Hydronic System

Disclaimer

I'm not a solar professional, not a plumber, not an electrician, not a builder, not an architect. I am a retired DIY-er. This document is made available for educational purposes only. I do not take any responsibility whatever for any damage, pain, inconvenience or monetary loss that may be the result of the reader utilizing any of the information in this article. To any readers of this document I make this statement:

Do your own research, make your own decisions and accept responsibility for yourself and your work. If you cannot or will not take responsibility for yourself then find someone else who will.

Acknowledgments

I am greatly indebted to many others who made their knowledge and experience available for others to use. I listed several links in the References section below.

However, I want to especially thank Gary Reysa whose web site builtitsolar.com contains a plethora of information.

There is a **ton** of information there. I suggest that the reader spend a lot of time looking thru that information. I am not going to repeat details in this doc that others have already well documented such as, how to make absorber fins, how to calculate collector and storage tank sizes, etc.

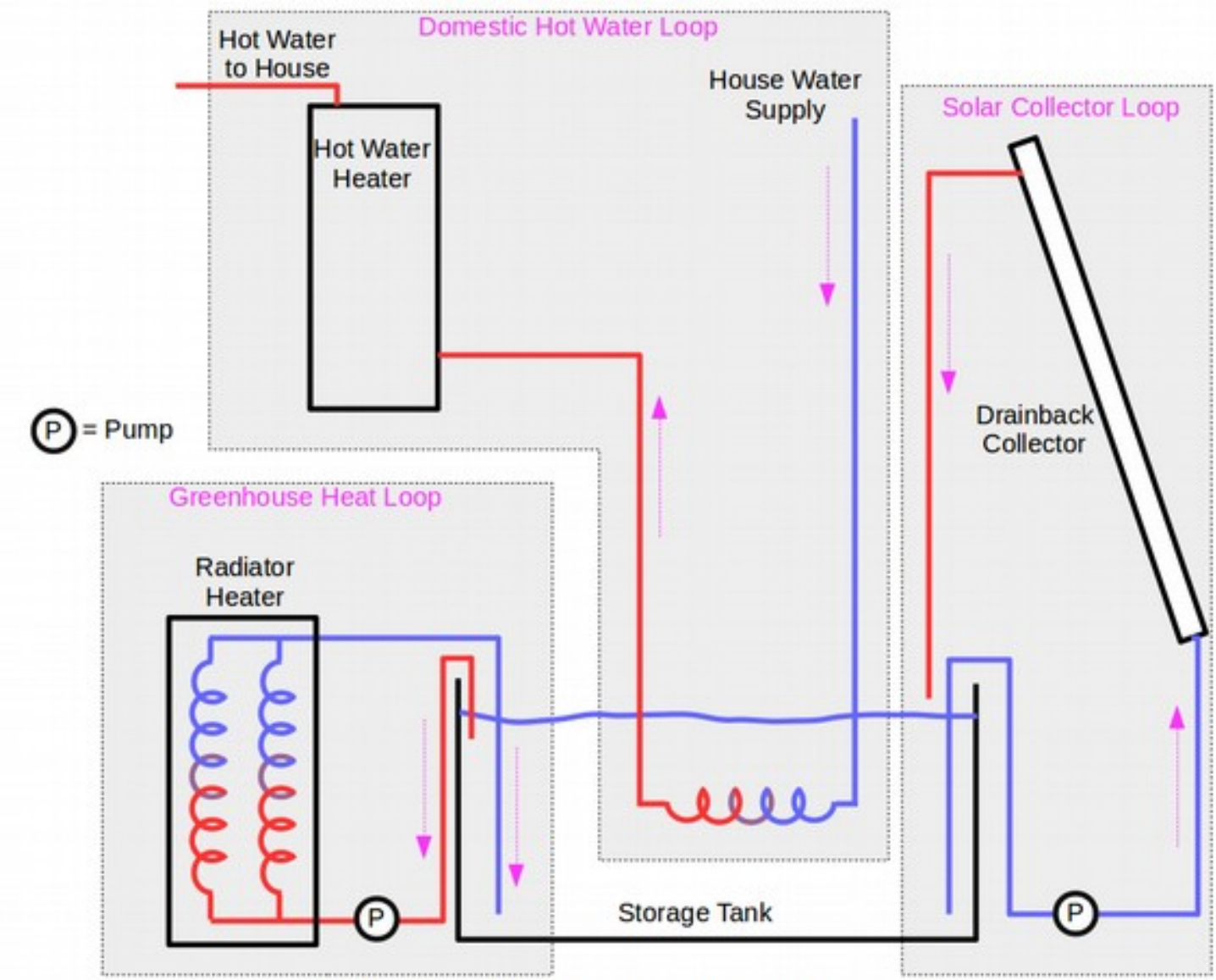
I literally spent hours and hours going thru the information on Gary's site (as well as some others), following links, making notes and ultimately coming up with my own personal design. My implementation clearly stands on the shoulders of the many people who have gone before me.

Overview

My hydronic (solar hot water) system is designed to do the following:

1) Capture energy from the sun (in the form of hot water)
2) Provide heat for domestic hot water
3) Provide heat to the greenhouse

The following simplified diagram shows the 3 subsystems (loops) for each of these objectives.



Hydronic System Simplified Diagram

Starting Point

Everyone has a unique starting point for planning and implementing a hydronic system. The design of the house, room for expansion or improvements, topography of the land, solar orientation, etc. are going to determine constraints on what you can or cannot do.

For my situation, here is my starting point.

Climate

My property is located at 9000' above sea level in Colorado. We get lots of sunshine year around (over 300 days / year are sunny) which is a plus for solar collection. However, our elevation and latitude mean that our location is not the best in terms of temperatures. High and low temperatures are lower than more southerly latitudes and lower altitudes.

House

I have a “round” (actually 14 sided) house that is 1000 sq. ft. in interior space. It sits on top of a crawlspace that is the same square footage. The nice thing about the crawlspace is that it has 6’8” headroom. It has a dirt floor which allows it to be called a crawlspace and does not count as “living space”. If I had poured a concrete floor it would be a basement and I would then have a 2000 sq. ft. house with higher taxes and more code restrictions. For example, in a crawlspace our local codes allow you to run electric wires and attach them with staples to the wall or ceiling; they do not have to be in conduit. I can also easily tap into existing water lines. Having a dirt floor allows me to easily add additional drain lines if needed.

Topography

The house sits on top of a hill with the entrance at ground level. The land slopes down to allow ground level entrance to the crawlspace.

The center picture window faces due south.

The Overall Plan

The overall plan is as follows:

1) Build a greenhouse (GH) that uses space underneath the deck and extends out from the deck. The crawlspace will be accessed by first entering the GH and then going into the crawlspace.
2) Utilize the crawlspace for:
    1) a work area to do gardening type activities such as mixing potting soil, preparing seedlings, etc.
    2) installing hydronic components

3) Build a solar hot water collector and attach to the deck.

Here is a picture showing the finished collector and GH:

Solar Storage Tank

The solar storage tank is the heart of the hydronic system. It contains the water medium into which all loops connect. The various loops either contribute heat to the tank or they extract heat from the tank.

Notes

Since this is a drainback design, the water level in the tank must be below the collector's plumbing. **There must be an air gap between the highest water level in the tank and the end of the return tube from the collector. If there is not, the collector will not drain and freezing temperatures will damage the collector plumbing.**

This drawing shows the relative elevations of the GH, collector and storage tank (inside the crawlspace):

Mount the circulating pump for the collector loop as close to bottom of tank as possible. This allows head pressure to keep the pump primed.

You should monitor the water level in the tank so you know when to add water to the tank. A sight glass in the plumbing allows you to view the tank water level when the collector water is fully drained back into the tank.

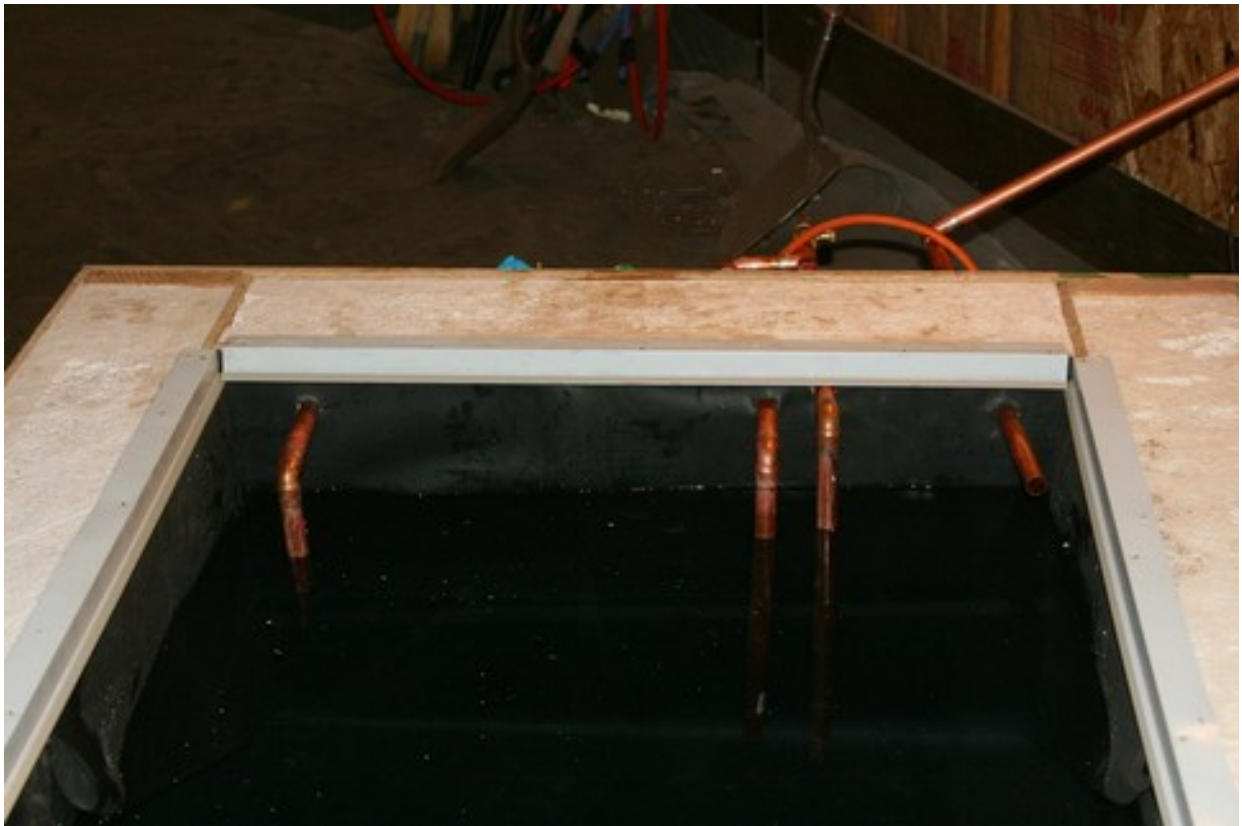
Construction

The builditsolar.com site has lots of good ideas for building the tank. I happened to have some SIPs cutouts left over from the construction of my house, so I designed my tank using these.

I dug down into the dirt floor of my crawlspace so the tank water level would be below the solar collector to allow full drainage of the collector when not in use. I wrapped the tank with plastic and back-filled around the tank.

Here is a picture of the tank bottom and sides made out of SIPs. The ends have plywood spanning the SIPs and tying them together. Also, notice there is a SIP at the bottom. These 8" thick SIPs provide a lot of strength plus very good insulation.

I lined the tank with EPDM. Then I put a metal channel around the top. Here is a picture showing this:



I then put holes thru the SIPs and EPDM below the top surface of the tank. This allows the tank top to go on and create a good seal. Also, notice the tube on the far right is the return tube coming from the top of the collector; it is **above** the water line.
I then laid a piece of EPDM around the top surface.

I created the tank top out of a SIP and put a lining of EPDM on it. This shows the underside of the top with the sensor well protruding thru the lid.

This shows the lid placed on top of the tank (but not in position yet):

Here is a pic taken later on after all the plumbing and electrical components are in place (and some junk already collecting on the top:

Take Time to Think It Thru!

I cannot emphasize enough how important it is to think thru all the plumbing components ahead of time, especially for a drainback system. Once the tank is in place, the collector location and elevation should be well defined. If not, you really don't want to go back and redo the tank.

Collector

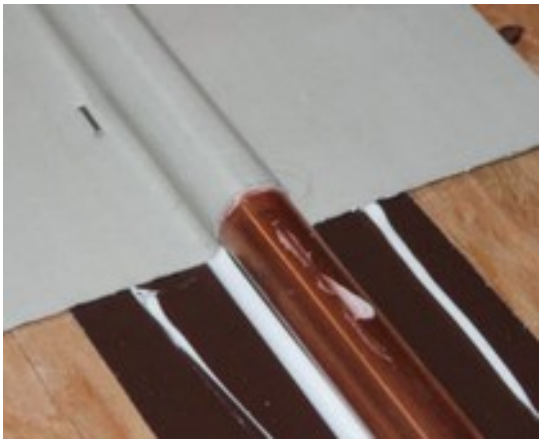
Collector Design

The objective of the collector is to collect and transfer heat as efficiently as possible to the fluid (water) in the tubes which then transfers its heat to the solar storage tank. Design elements that hinder the collection and transfer of heat should be avoided. Every additional layer of material that stands between the solar radiation and the water in the tube decreases the efficiency of the process.

Copper tubes exposed directly to the sun and painted black with a low emissivity paint will collect and transfer the heat in the most direct and efficient manner. The most efficient design would be a whole lot of copper tubes very close together. However, that would be very expensive. A compromise is to space the tubes further apart and use absorber fins to collect heat falling on the collector in between the tubes and transfer heat to the tubes by conduction. This is the design most frequently used in DIY collectors.

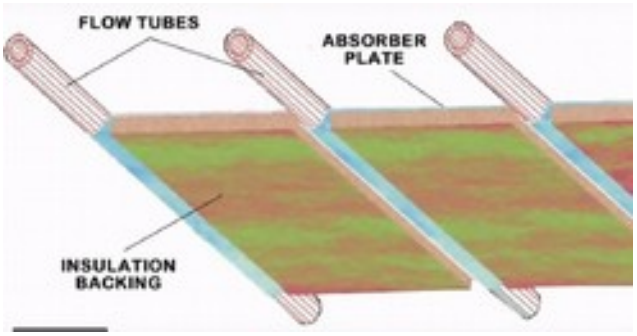
Absorber Fins

The design for many DIY collectors utilizes absorber fins that are placed on top of the tubes, squeezed around the tubes to achieve maximum physical contact and held in place by staples or screws. Additional enhancements include silicone sealant to fill any air gaps and an additional piece of aluminum underneath the tubes to enhance contact and heat transfer from the fins to the tubes. Here is an example of this type of design. This design seems to have performed well for many DIY collectors. (click here for details on this design).



In thinking about this design, I wondered if the aluminum on top of the tube was decreasing the efficiency of the heat transfer process by introducing a layer of material between the sun and the tube to which you are trying to transfer the heat.

The thermal conductivity of copper is almost twice that of aluminum. Why hinder that by placing aluminum **on top** of the copper? Being a typical DIYer, I had to wonder if there might be a better design out there.



I ran across a design that puts the absorber fins **underneath** the tube and thought that made more sense from a heat transfer efficiency point of view. Having the fins to go under the tubes allows the copper tubes to directly capture solar radiation on the side that is exposed to the sun. Since the underneath side of the tubes is not being hit by the sun, this is where we contact the aluminum to the copper and transfer the heat collected by the fins to the tubes. (Click here to see where I got this idea)

So, if I went with this design the next step is figure out how to attach the absorber fins to copper tubing. Since the aluminum is not on top of the tube, I can't screw or staple it down over top of the copper tubes.

Details on how I made the absorber fins are below.

Stagnation

During my investigation into collector design, one of the things I became a bit concerned about was the issue of stagnation. Stagnation is when no more heat is needed in the storage tank and the collector is not pumping fluid thru the pipes. This can cause very high temperatures inside the collector. These high temperatures can cause several problems:

- insulation can release gases (outgassing). These gases can build up on the inside of the glazing, reducing the solar radiation gain.
- damage to collector – very high temps can damage parts of the collector, including the glazing

The builditsolar.com site has several articles which discuss stagnation.

Since part of the purpose of the hydronic system is to heat my greenhouse in the winter, I found that I had some options for addressing the stagnation issue. I will go into detail on these options later.

Collector Angle

The collector ideally needs to face due south (true south, not magnetic south) and be angled to collect the most energy from the sun. Since my collector is going to be at a fixed angle, I had to determine the best year-round average angle to use for my needs. For my implementation I need more heat in the winter than in the summer. In the summer, I'm only heating domestic hot water. In the winter, I'm also heating the greenhouse. So, I want to optimize it for winter usage.

NOTE: Some solar collector calculations measure the angle from horizontal while others measure from vertical. Make sure you're paying attention.

This page calculates the angle from horizontal:
https://www.solarpoweristhefuture.com/how-to-figure-correct-angle-for-solar-panels.shtml
shows how to calculate collector angles.

Method 1 is quick and easy, but less precise. My latitude is 38.7°, so my "optimum" angle for best winter collection would be 53.7°. Using method 2a, I come up with 63.8°.

This page calculates the angle from vertical:
http://www.solarelectricityhandbook.com/solar-angle-calculator.html

The best winter angle for me (from vertical) in this calculation is 28° (for January). This would be 62° from horizontal. So, the calculations are pretty close to the same.

Gary Reysa has an interesting discussion on collector angles in his $2K Solar Space + Water Heating article in the Collector Design section. He revisited his vertical collector design thoughts several times. This is good reading and gives some insight as to what each person should consider for their situation.

I went with 35° from vertical (55° from horizontal). With this angle I have brief stagnations periods in spring and fall and none in the summer. If I were to angle it more (say 28° from vertical, 62° from

horizontal) I might not have any stagnation issues. I am thinking about changing the angle for next year. If I do, I'll update this article.

Collector Notes

The collector is 14′ long by 7′ high. The dimensions and location are influenced by my specific situation. Here are the main influencing factors on my collector design:

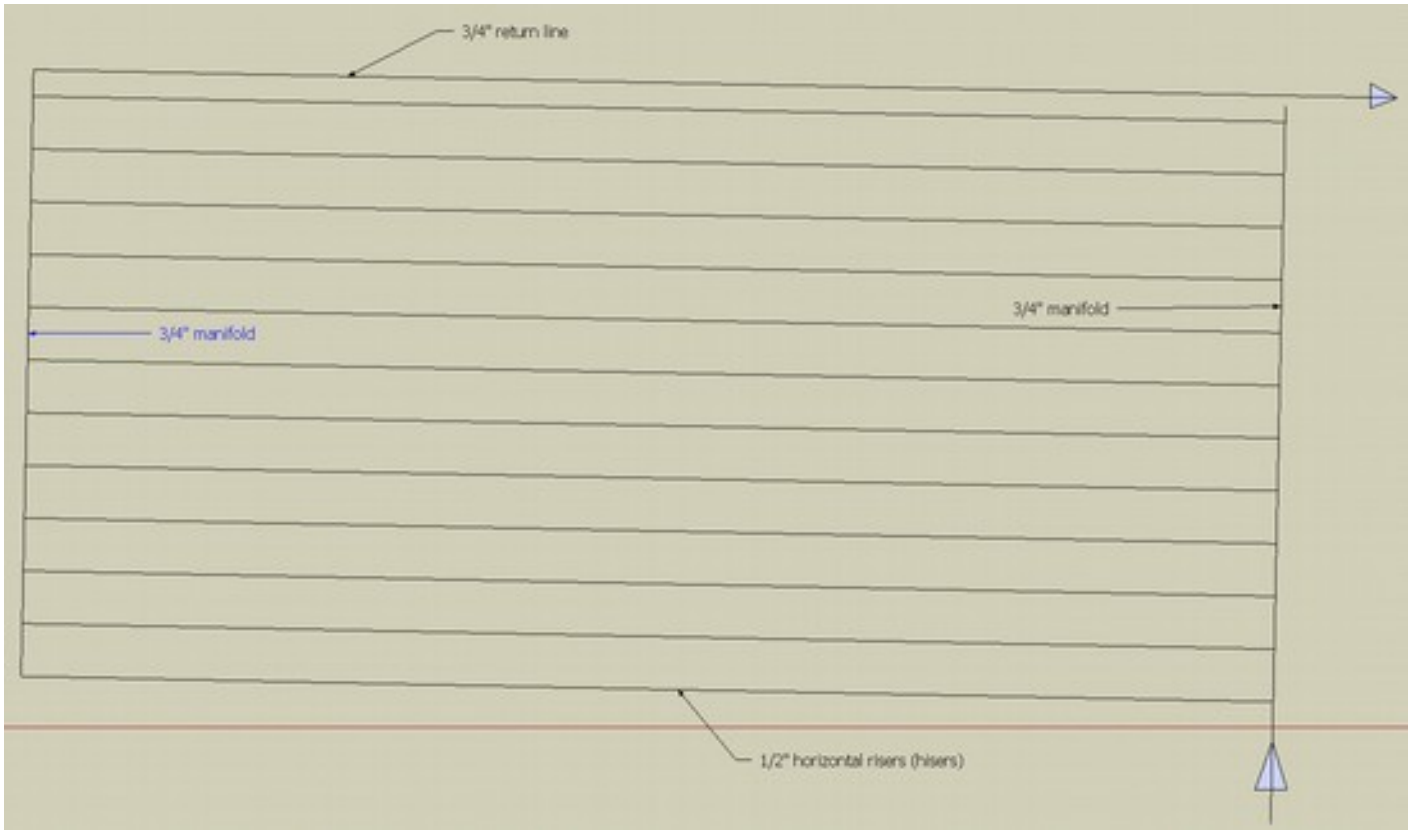
1) Size: I was aiming for approximately 100 sq. ft. This would give me 40 sq. ft. for domestic hot water (DHW) heat and 60 sq. ft. for GH heating
2) I wanted to locate the collector as close to the crawlspace as possible to minimize heat loss in the plumbing to and from the storage tank
3) The bottom of the collector had to be higher than the storage tank water level in the crawl space in order to accommodate drain back from the collector. Starting at the bottom and measuring up to determine the height of the collector I stopped at 7′ so as to not obstruct the view from the deck.
4) Using the deck as part of the collector support structure made construction simpler (as opposed to a self-supporting structure separate from the house)
5) Since the collector is wider than it is high, I decided to use a "hiser" (horizontal riser) approach to reduce the number of soldered connections

Grid Layout

As previously mentioned, I went with a "hiser" configuration. "Hiser" is short for "horizontal risers. The supply line, return line and manifolds are 3/4" diameter. The horizontal runs are 1/2" dia.

A tee is used at the top of the right manifold. This helps to provide equal pressure across the horizontal runs. Ideally, a tee would also be used at the lower left manifold for the same reason, to provide equal pressure across the horizontal runs. However, since this was at the bottom of the grid, it would not drain. If the water left in this tee freezes, it would not likely cause a pipe break since it can expand up the manifold as it freezes. However, I didn't want to take a chance on this, so I used an elbow there.

Here is a sketch of the grid layout:



Order of Construction

- Build supporting structure for frame
- build frame (2x6 and 1/2" exterior grade plywood) and attach to structure
- build and leak test collector grid
- make and attach absorber fins
- set grid in the frame and paint
- remove grid from frame and install polyisocyanurate (polyiso) insulation layer
- lay grid in position on top of polyiso insulation; set bottom on spacer blocks to achieve desired slope; mark grid outline; this shows where rock wool insulation needs to be installed (in between the pipes)
- remove grid and install rock wool insulation
- determine hole location for inlet and outlet pipes and drill holes in frame back
- install grid; set bottom on spacer blocks to achieve desired slope; attach top with wire to allow it to move due to expansion/contraction
- install temperature sensor
- seal holes around inlet and outlet
- install supports for glazing
- install polycarbonate glazing
- install finish flashing around frame

Support and Frame

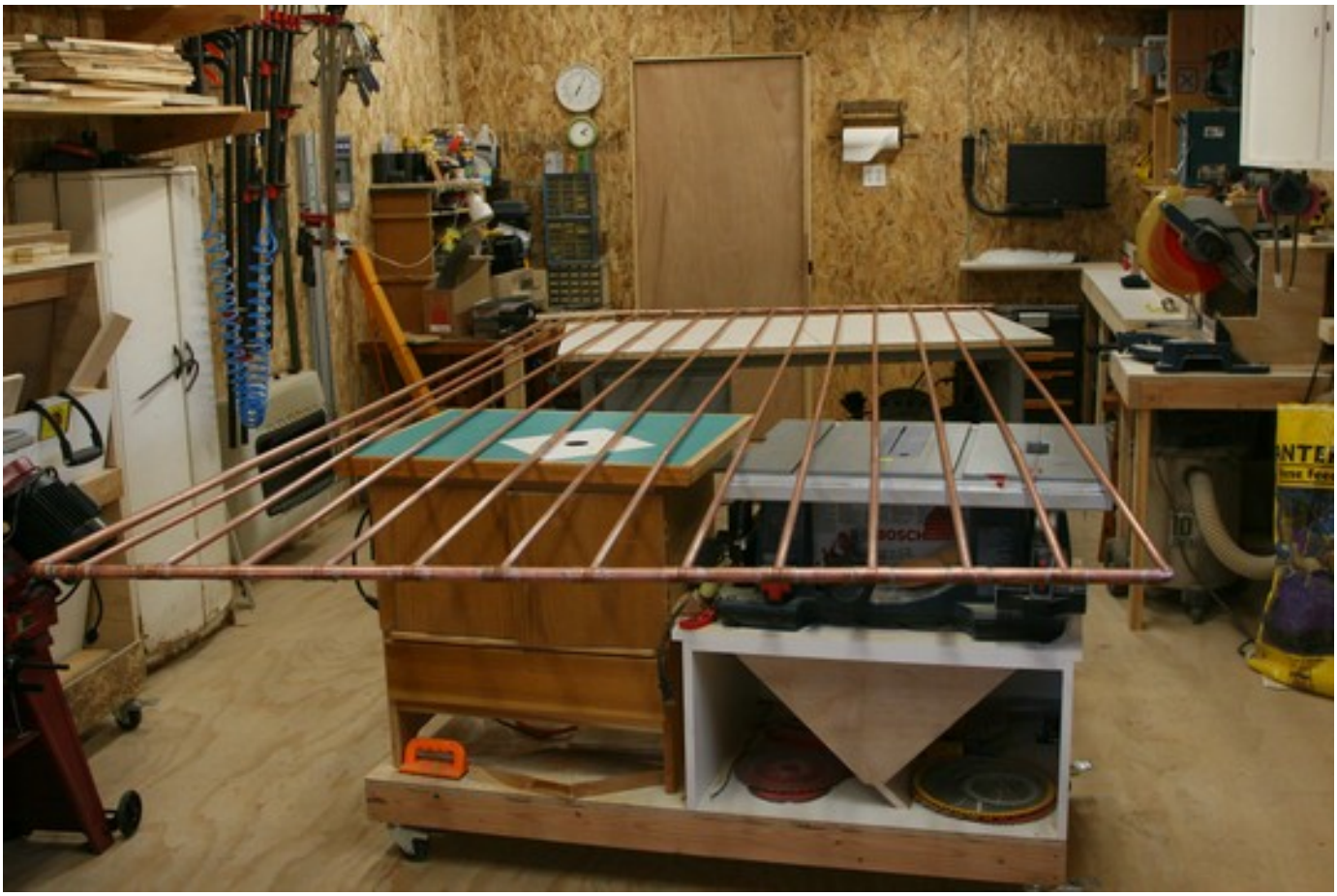
I used 2x6's to build a frame to support the collector. It is attached to the deck at the top and sits on concrete pads on the ground. The bottom of the collector is about 34" above the crawlspace floor (see elevation sketch above). I cannot emphasize this enough: **the collector return pipe must be above the water level in the storage tank to allow for drainback.**

Here is the frame with 1/2" exterior grade plywood attached to the back:

In this pic, I am placing the absorber fins in the frame for painting.

Plumbing the Grid

I laid out and assembled the grid in my workshop. I was able to set it on top of my worktables. This made it much more convenient to solder; I actually sat on a stool and did most of the soldering while sitting.



This pic shows a closeup of the return line at the top of the grid. I attached a SharkBite valve with a hose fitting to both the supply and return lines. This allowed me to hook up a garden hose to run my leak test.

The SharkBite valves were then removed and used elsewhere in the collector tank plumbing.

Absorber Fins

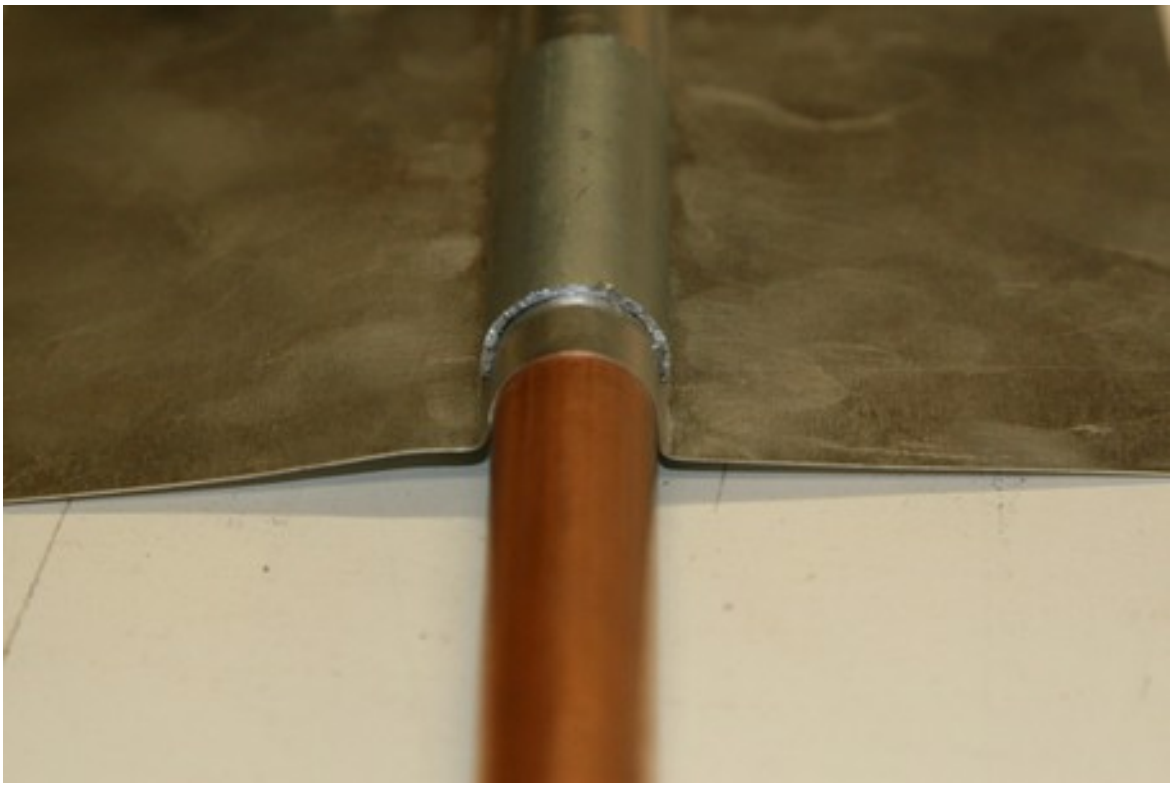
Making the fins

As I mentioned above, I made my absorber fins to go underneath the copper tubes instead of the more common method of putting them on top of the tubes. There are many good ideas about how to make these fins on the builditsolar.com site.

Attaching Fins to Tubes

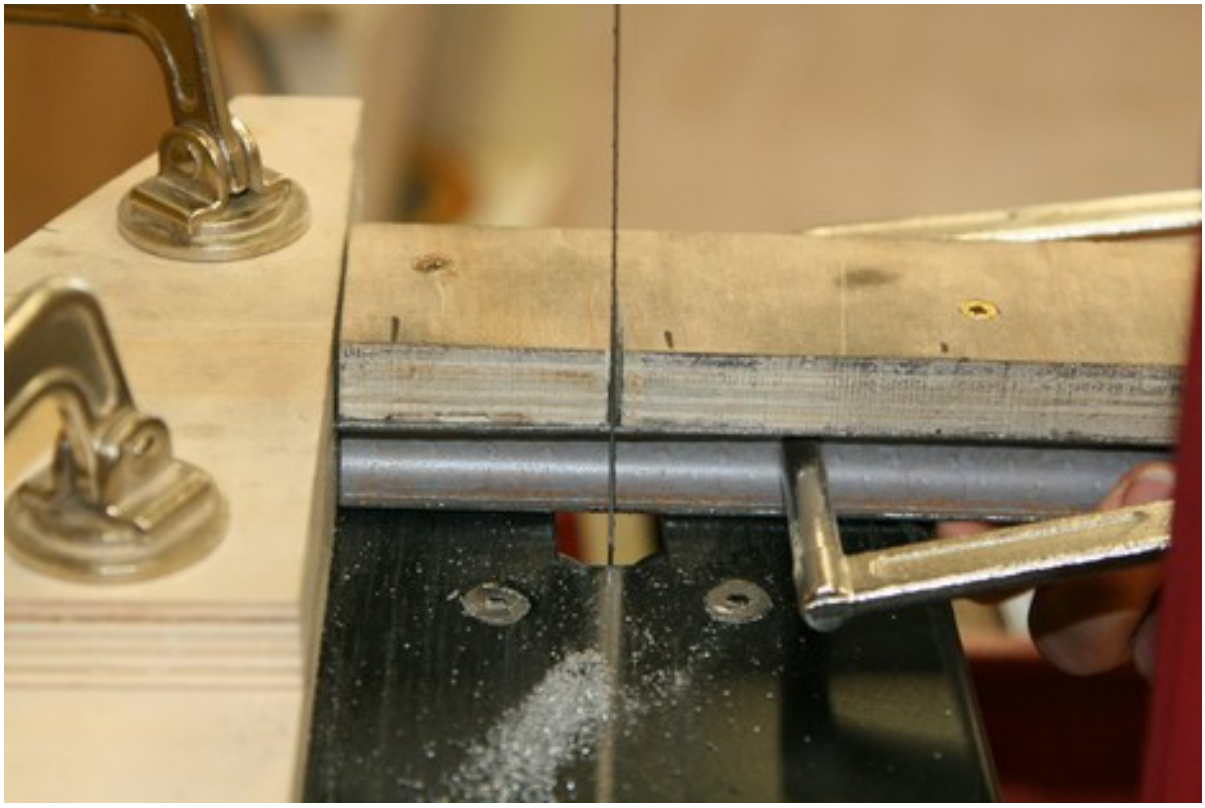
I had to come up with a different method for attaching my fins on the bottom side of the copper tubing. I discovered that 3/4″ EMT conduit is a perfect fit over a 1/2″ copper tube. So, I made clips out of EMT and they were used to press fit the fins onto the tubing.

Here is a closeup of an EMT clip pressed down over the fin and pinching it onto the copper tubing: Notice how snug the contact is between the fin and the tubing.



I cut the EMT into 10” lengths. I then made a jig and cut the EMT along its length as shown:

Then I turned the jig 90 degrees and cut (5) 2” long pieces from the 10” tube:



The end result is a 2” long clip that will press down over the fin and hold it tightly to the tubing. It takes a bit of experimentation to cut just the right amount off the EMT to have a clip that takes a little effort to press on and will not easily come off. Once I got this figured out, it really didn’t take long to make the clips; a few hours for all the clips I needed for the entire grid.

Preparation Before Painting

Before attaching the fins to the grid, I cleaned the fins with a metal cleaner, rinsed and let them dry.

Assembling the Fins

I used a minimal amount of silicone sealant in the bottom of the groove in the fin and then attached the fins using the clips.

Painting the Grid

After the fins were attached to the entire grid, I put the completed grid into the frame (temporarily) and applied high temperature black spray paint.

End Result of My “New” Fin Design

I honestly don’t know if my method for fins is any better than other methods from an efficiency point of view. I know I spent a lot of time figuring out how to attach the fins (using EMT clips). Not everyone has some of the equipment that I needed to make the clips (e.g. metal cutting band saw).

I probably could have saved some time and done it the way many others have done it. However, it was just one of those “I just want to try it this way” kind of things.

I do know that the collector seems to be working very well. For example, if my 200 gallon storage tank temperature is 80° F and the sun is shining on a 40° day, I can gain 30 – 35° in the tank in a single day.

Collector Insulation

Insulation and Outgassing

Polyisocyanurate hard insulation seems to be the most commonly used insulation for DIY collectors. However, I read that this insulation could release gasses inside the collector during very high temperatures (e.g. stagnation).

I discovered that mineral wool insulation (aka rock wool) provides extremely good thermal insulation and high efficiency. It is also rated for much higher temperatures and it does not outgas. However, it’s pretty expensive. So, I installed a layer of polyisocyanurate insulation and then mineral wool insulation on top of that, where the absorber fins came into direct contact.

Installing the Insulation

I installed 1” polyisocyanurate hard insulation layer. I then placed the grid on top of this and marked where the copper tubing went. I made sure to place the grid in its final location including sloping it for proper drainage.

I then removed the grid and installed the mineral wool insulation.

You can see the chalk lines that show where the grid goes.

Here is the grid installed on top of the rock wool insulation layer:

Note the slope of the grid to provide for completely draining the grid.

I filled in the rest of the outside perimeter of the grid with mineral wool insulation.

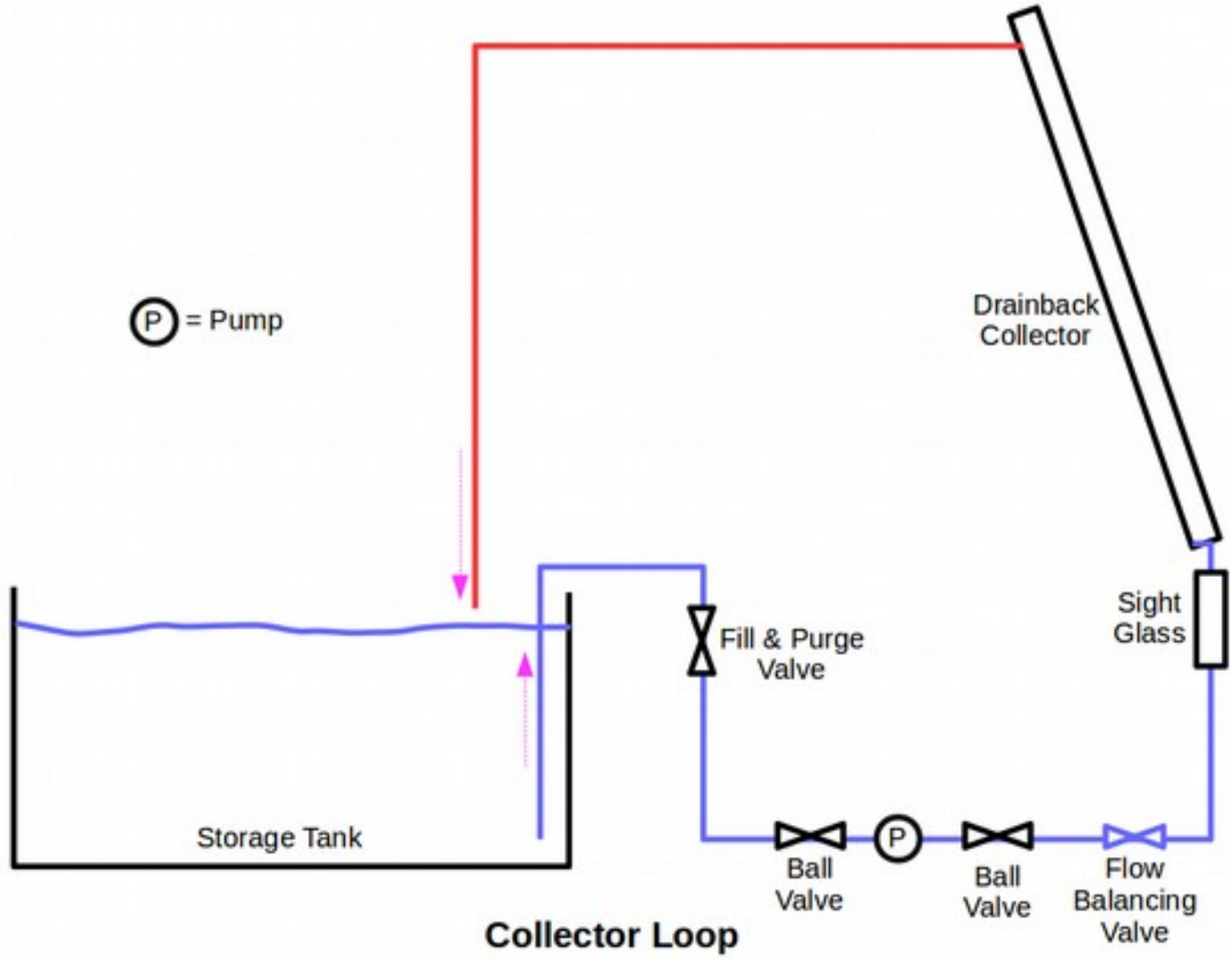
The temperature sensor that is used by the differential controller to turn on/off the pump that supplies water thru the grid was installed. This pic shows the upper, left corner of the grid (the highest point on the grid) with a temperature sensor attached. The sensor wire comes in from the back of the frame.

Next, I added supports for the glazing:

Here is the finished collector with glazing and sheet metal covering the perimeter:

Plumbing Details

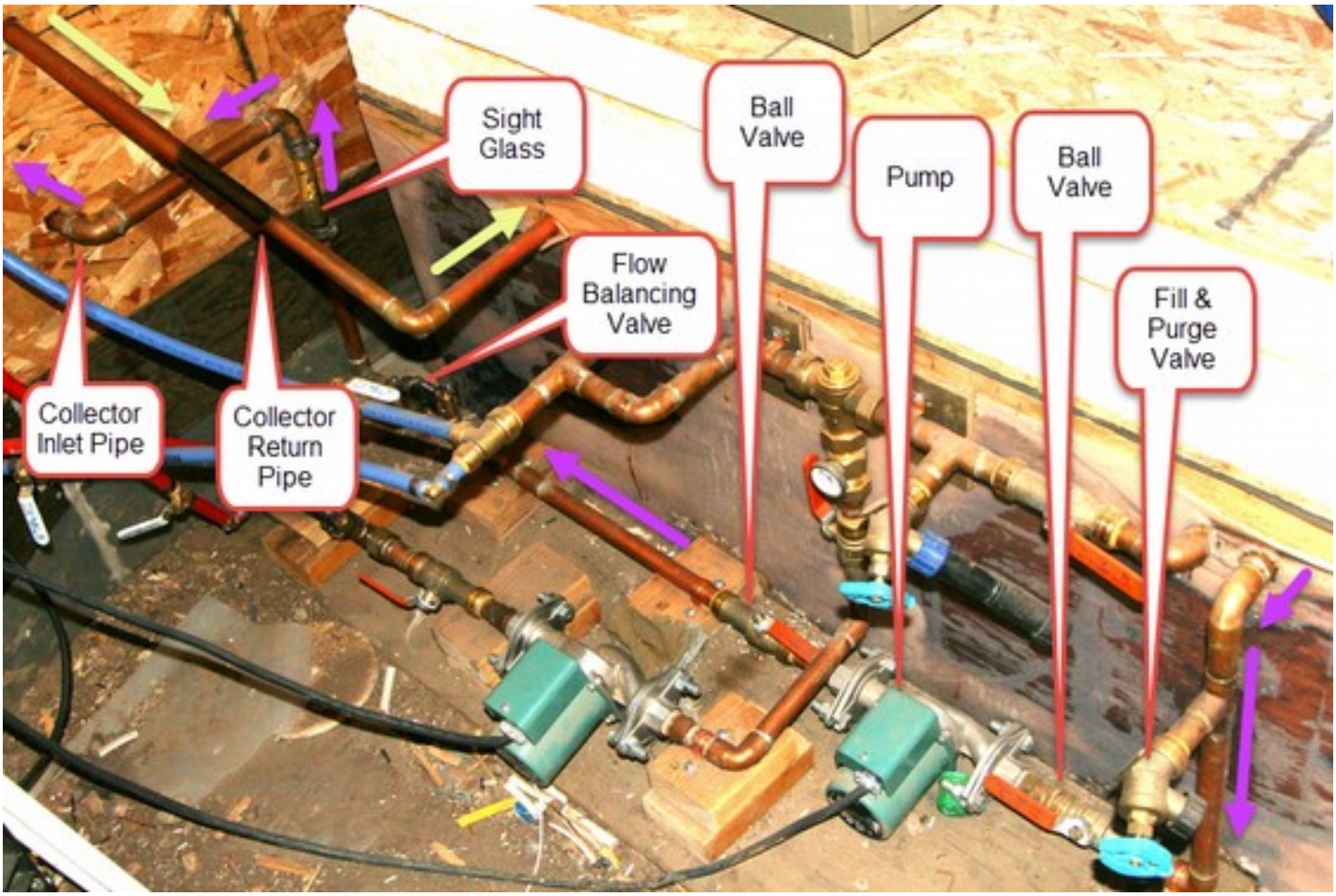
Here is the collector loop plumbing diagram:



The components for the plumbing loop for the collector consists of:

- Taco 008 Stainless Steel Circulating Pump (no check valve)
- Caleffi 3/4" NPT QuickSetter Balancing Valve w/ Flow Meter; SKU: 132552A
- (2) ball valves
- (1) fill and purge valve
- sight glass

Here is a picture of my collector loop at the storage tank. Purple arrows indicate flow from tank to collector. Yellow arrows show return flow from collector:



Notes:

- I insulated the outside supply and return pipes running from the collector thru the exterior wall to minimize heat loss. Make sure any insulation around pipes in the collector loop is rated for high enough temperatures; **foam insulation isn't**!
- I added a union (a fitting with threads) in both supply and return lines of the collector to allow disconnecting from collector if necessary

This picture shows the supply and return plumbing lines from the collector, wrapped in insulation. Both lines **must** slope back to the storage tank in order to enable proper drainback when the pump is not running.


Collector
Return Pipe
Collector Input
Pipe

Greenhouse Heating

Notes

I originally designed the greenhouse (GH) with in-floor radiant heating. I did a lot of research before building this into the GH. Unfortunately, I did not find much about doing this for raised beds (which we use in both the GH and in the garden). It turned out that the GH had so much thermal mass in it that the in-floor radiant heating didn't add the benefit that I thought it would. The soil temp in the beds stayed at 60 deg. or higher all winter long. The radiant heat coming up thru the floor and into the beds wasn't necessary. And, the air temperature would drop too low to keep the plants happy. So, I repurposed the radiant floor loop to put the hot water thru a radiator which did a great job at keeping the air temperature up. I was able to keep the air temp to a minimum of 50 degrees at night even when we had sub-zero temperatures outside.

One might think that the in-floor tubing was a waste of time. However, it turns out I was able to use that when I ran into stagnation issues (details later).

Materials

Pump

Taco 007 Stainless Steel Pump with IFC (check valve)

Mixing Valve

3/4" Union Sweat Mixing Valve w/ Temperature Gauge; PN: 5003-C3-G

(3) ball valves

fill &air purge valve (Shark bite that I already had bought for testing the collector loop)

Domestic Hot Water (DHW) Loop

Notes

Multiple scenarios possible

Can I prioritize the solar storage tank temperature for radiant heating and use what is left over for DHW?

Materials

Mixing Valve

3/4" Union Sweat Mixing Valve w/ Temperature Gauge; PN: 5003-C3-G

Set max temp to 110 degrees

Collector Stagnation

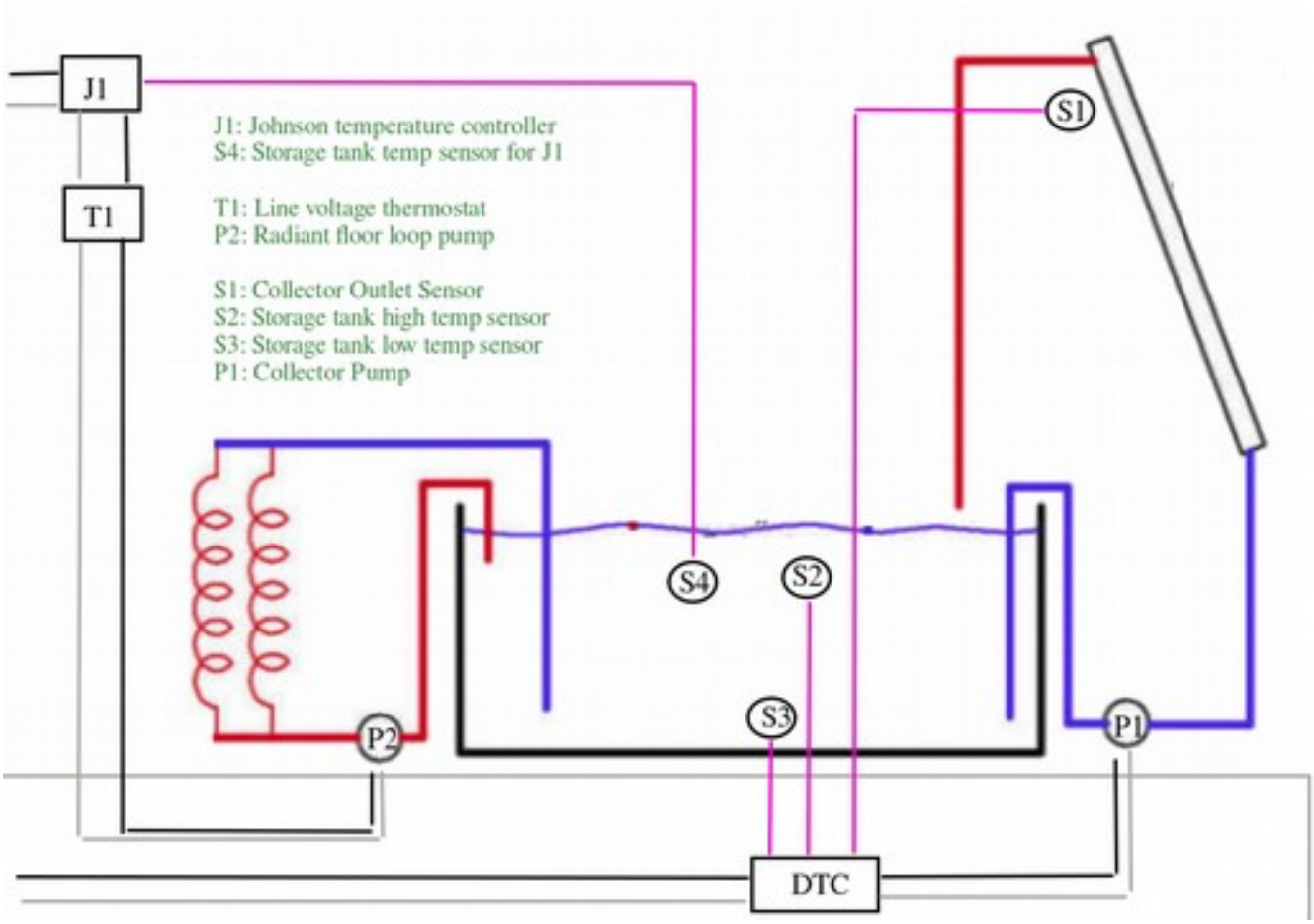
Options for Dealing With Stagnation

1. Increase collector angle so it is less prone to overheat in the summer

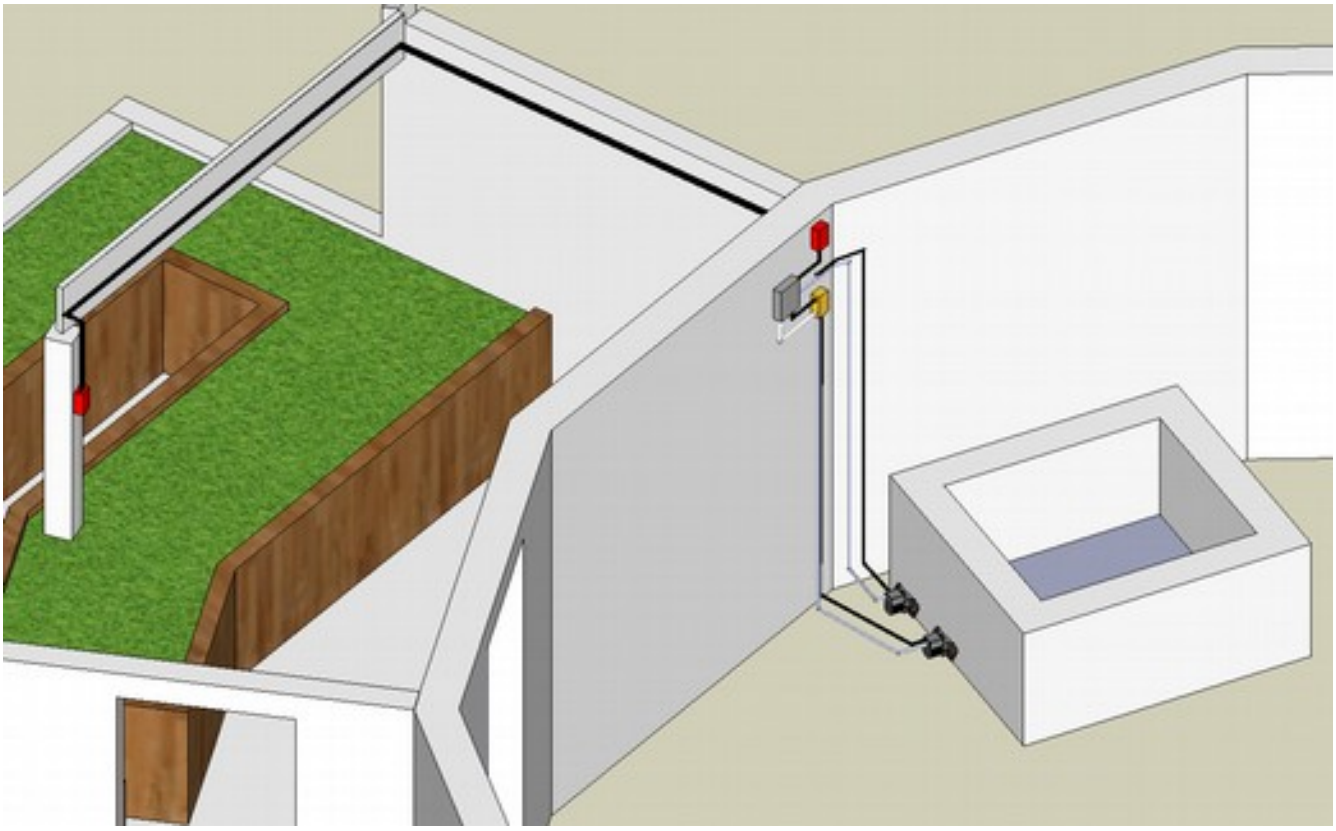
2. Install an overhang so the the collector is partially shaded during the summer to help prevent overheating
3. Add a roll-up shade cloth and adjust it up or down as the seasons progress
4. Add a loop to the hydronic system that circulates the water thru a loop which dissipates the heat when the tank temperature reaches its set maximum

Electronics

When storage tank is above min. temperature (S4), the Johnson controller closes and provides power to the GH thermostat (T1)



Thermostat turns on pump (P2)



Collector Loop

DTC

(3) sensors

18 ga. Wire for sensors (thermostat wire)

(S1) outlet temp sensor; mount to outlet tube outside of collector; use SS zip ties; insulate

(S2) high limit sensor in same tube in tank at the top

(S3) tank sensor: inside copper tube located near bottom

When (S1) is higher than (S3) and less than (S2) DTC turns on pump (P1)

When storage tank is above min. temperature (S4), the Johnson controller closes and provides power to the GH thermostat (T1)

Thermostat turns on pump (P2)

Greenhouse Radiator Heater Loop

Materials:

(S4) Storage Tank Temperature Sensor

(J1) Johnson Controls A419ABC-1C Electronic Temp Controller

(T1) GH Thermostat

line voltage thermostat to turn on pump

When storage tank is above min. temperature (S4), the Johnson controller closes and provides power to the GH thermostat (T1)

Thermostat turns on pump (P2)

Delay Timer ?

A delay timer on the pump system delays reengagement of the pump upon shut down for at least 5 minutes. This is so the water can completely drain back on shut down before trying to start up again. If it doesn’t the pump has a strong chance of catching air coming back through the plumbing and air locking the pump.

Data Logging

Look into Arduino and Pi options

Raspberry Pi

http://www.briandorey.com/post/raspberry-pi-solar-data-logger-version-2

Collector Performance

Tweaking the Collector Loop

Flow

Collector Angle

Stagnation

Data

Assumptions

Tank size (gal): 200
Lbs of water: 1660

27Nov2017

Hours of Collection: 8:45AM to 3:15PM
Low Outside Temp During Collection: 53.5 °
High Outside Temp During Collection: 60.3 °
Wind Speed Average: 24 MPH
Cloud Cover: Sunny

Data

Hrs. of collection: 6.5
Starting tank temp: 75
Ending tank temp: 115
BTU's collected: 66400
kWh equivalent: 19.46
kWh to run pump: 0.63
Net kWh equivalent: 18.83
Tank temp next morning (7AM): 113

28Nov2017

Low Outside Temp During Collection: 27 °
High Outside Temp During Collection: 42.3 °

Wind Speed Average: 8MPH
Cloud Cover: Mostly Sunny

Data

Starting tank temp: 113
Ending tank temp: 131
BTU's collected: 26560
kWh equivalent: 7.78

Tank temp next morning (7AM): 129

29Nov2017

Low Outside Temp During Collection: 44.6 °
High Outside Temp During Collection: 59 °
Wind Speed Average: 16MPH
Cloud Cover: Sunny

Data

Collector was running by 9AM
Starting tank temp: 129
Ending tank temp: 155

Greenhouse Heating Performance

29-30Nov2017

Setup

mixing valve set to 110 °
Flow valve turned to ½
5:15PM: Set Johnson to 140 °; set thermostat to 60 °; radiant floor pump turned on

Data

8:30PM tank was at 140 °; pump had turned off; set down to 135 °
Estimated another hour before tank temp reached 135 and pump turned off;

	5PM	7:30AM
Air Temp	64.7	50.5
Soil Temp		68

Floor Temp	55	52
Tank Temp	155	132

Outside Temps (from 5PM to 7:30AM window)

Low: 11

High: 30

30-31Nov2017

Setup

Flow valve turned to just a “dribble”

5PM: Set Johnson to 120 °; set thermostat to 60 °; radiant floor pump turned on

7:30 AM pump was not running

Data

	5PM	7:30AM
GH Air Temp	62	54
GH Soil Temp	68	68
GH Floor Temp	59	57
Tank Temp	147	118

Outside Temps (from 5PM to 7:30AM window)

Low: 22

High: 35

31Nov-1Dec2017

Setup

Found out that collector was kicking on early and actually dropping tank temp by 10 ° before it started gaining heat again. Turned off pump and turned on manually a bit later (10PM) to gain heat. Ran pump manually until 2:30PM, when the collector was about done collecting heat. Installed new iSolar Plus DTC and switched over to this after the collector was no longer collecting heat. The iSolar gives temp readouts of all temp sensors (both tank and collector) so this should really help in data collection/troubleshooting.

At 7:30AM, the next morning, I was surprised to see a huge difference in bottom and top tank temps:

bottom: 86 °

top: 124 °

The Johnson sensor located in the middle showed 113.

So, the original DTC was working as expected. It would kick on at +20 above bottom sensor. However, this temp was still lower than the overall average temp of the tank. In the case of the figures above, the pump would have kicked on at 106 deg, 7 deg lower than the overall average tank temp. Therefore, it would have cooled the tank down for a bit until the collector temp got higher.

For today, I set up the turn on delta T to 29 ° (that's the max this controller allows). So, the collector should kick on at around 115 ° .

6PM: Tank temp was 135, so I set Johnson to 115 °; set thermostat to 60 °; radiant floor pump turned on

7:30 AM pump was not running

Data

	6PM	7:30AM
GH Air Temp	62	53
GH Soil Temp	68	68
GH Floor Temp	61	56
Tank Temp	135	113

Outside Temps (from 5PM to 7:30AM window)

Low: 15.9

High: 40.9

1/2Dec2017

Setup

5PM: Tank temp was 133, set Johnson to 115 °; set thermostat to 55 °; radiant floor pump is not on

This is an experiment to see how much thermal mass heat is being released into the GH without any supplemental heat. If the GH air temp gets to 55 the floor heat should kick on, but it will take a while to have an impact.

Stratification seems to be excessive when pumps are off. The hypothesis is that hotter temps are at one end of the tank where the pipes are and colder water at the other end. I extended the collector return pipe about a foot in order to get water further back in the tank.

7:30 AM

floor pump had kicked on and lowered tank temp.

Stratification – low: 85°, high 125°; extending collector return pipe didn't seem to help

Data

	5PM	7:30AM
GH Air Temp	65	56
GH Soil Temp	72	70
GH Floor Temp	62	59
Tank Temp	133	113

Outside Temps (from 5PM to 7:30AM window)
Low: 26 °
High: 41 °

3/4Dec2017

Setup

5PM: set Johnson to 107 °; set thermostat to 55 °; radiant floor pump is not on

7:30 AM
floor pump had kicked on and lowered tank temp.
Stratification: 87 low: °, 127 high °;

Data

	5PM	7:30AM
GH Air Temp	62	54
GH Soil Temp	72	70
GH Floor Temp	62	60
Tank Temp	127	107

Outside Temps (from 5PM to 7:30AM window)
Low: 16
High: 40

4/5Dec2017

Setup

I opened the ball valve all the way and set the DTC to manage to motor speed. During the collector fill up the motor ran full speed. This resulted in 7 GPM during fill up (the flow valve is still in line and is limiting this to 7GPM; otherwise it would have been more). After fill up, motor speed was cut to 30%; this resulted in 4 GPM. 30% is the minimum setting for motor speed. I let it run at that setting and the heat collected seemed to do about as well as running at 2.5 GPM. This is certainly a subjective "feel" at this point since the outside temp was much lower than previous days. The tank gained 22 deg. from the collector. For such a cold and windy day, I thought this was not too bad.
If I want to reduce the flow to lower than 4 GPM, I'll have to closed down the ball valve a bit to obtain this.

Predicted to be very cold tonight; set thermostat to 52°; set Johnson to give 25° before it kicks off (102°)

Data

	5PM		7:30AM
Tank Temp	129	Set Johnson to 102	104
GH Air Temp	64		49
GH Soil Temp	72		70
GH Floor Temp	62		51

7:30 AM
Stratification: low: 91°, high 118°

Outside Temps (from 5PM to 7:30AM window)
Low: -1°
High: 17°

References and Detailed Notes

BuildIt Solar

http://www.builditsolar.com/Projects/SpaceHeating/DHWplusSpace/Main.htm

Horizontal (Hiser) Examples

http://www.builditsolar.com/Projects/SpaceHeating/RobHizer/Rob's%20Solar%20Hot%20Water%20system%20V3.pdf

http://www.builditsolar.com/Projects/SpaceHeating/Hiser/Hiser.htm

http://www.builditsolarblog.com/2012/10/

Paul's DIY Solar Water Heating System

http://www.builditsolar.com/Projects/WaterHeating/Metal1K/Metal1K.htm

Uses low-e paint and a thermally conductive copper adhesive bond absorber fins to riser tubes.

Hiser Technical Study

http://orbit.dtu.dk/files/3049319/JianhuaFanSEJpreprint.pdf

Tips and Tricks

https://www.aluminum-solar-absorbers.com/tips-and-tricks

(contains other links to controllers, etc.)

SketchUp

I used SketchUp to design this project on the computer. For more details click here.

Collector Flow Rate and Pressure Drop

Here is what I estimated for the flow and pressure drops:

1) Estimated flow: 3.92gpm

2) vertical distance between top of collector and tank water level: 8 ft + 1.25% = 10 ft. of static (startup) head

3) Pressure drop for the plumbing system: 0.896 psi flow velocity: 2.5 ft/s