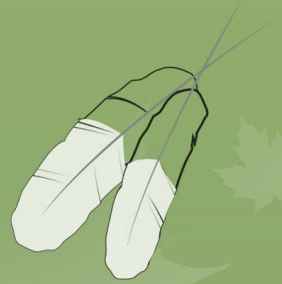




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A Solar Thermal Collector Fabrication Plan and Hot Water System Installation Guide for Indigenous Communities

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References for Design:

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Disclaimer:

The aim of this publication is to provide information to empower youth and others in Indigenous communities to develop skills and generate economic opportunity through the process of building, installing and maintaining solar systems for sanitary hot water.

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Table of Contents

Project Background.....	1
Overview of the Fabrication Plan and Installation Guide	2
Personal Protective Equipment (PPE)	3
Recommended Health and Safety Training	4
PART 1: Solar Thermal Collector Fabrication Plan	5
STEP1 - Absorber Jig.....	5
STEP2 - Absorber Piping.....	11
STEP 3 - Absorber Fin	16
STEP 4 - Absorber Assembly.....	18
STEP 5 - Collector Frame	24
STEP 6 - Collector Assembly.....	29
STEP 7 - Collector Casing.....	34
PART 2: Solar Hot Water System Installation.....	51
Collector Location and Orientation.....	51
Collector Location and Shading Considerations	51
Collector Mounting Angle	52
Collector Orientation	52
Seasonal Optimisation	52
Collector Mounting	53
Various Mounting Methods for Asphalt-Shingled Roofs	54
Roof Mounting using Structural Blocking between Truss Top Chords	55
Wall Mounting	56
Collector Headers and Distribution Piping.....	58
Fabricating the Collector Headers	59
Distribution Piping in Roof Installations	59
Distribution Piping in Wall Installations.....	60
Thermal Insulation of Collector Headers and Distribution Piping	60
Collector Temperature Sensor Installation	60
Balance of System Installation	61
Balance of System Installation When Using a New Solar Storage Tank.	62

Table of Contents

Application Tips for Retrofit Installations Using Existing Electric Storage Tanks.....	65
Balance of System Installation When Using an Existing Electric Storage Tank (with modifications) .	70
System Fill and Commissioning.....	73
References and Resource Materials	75
Appendix 1: System Demonstration Installation Examples	76
Demonstration 1	76
Demonstration 2	77
Demonstration 3	78

Project Background

In collaboration with Pikangikum First Nation Band Council and Habitat for Humanity Indigenous Housing Partnership, a project vision was created to help guide the objectives of this project. This vision stated that the project should:

- Promote the seven generations concept by using resources sustainably so as to allow for equal access seven generations from now.
- Create opportunities for youth through skills development in trades (plumbing, woodworking, electrical, construction) and foster a sense of accomplishment among youth.
- Create economic development by sourcing tools and materials from indigenous owned entities where possible, use lumber from local sources and lead to the opportunity to sell solar collectors to community members.
- Encourage community development by promoting solar collectors built by the community for the community.
- Enhance hygiene and health through the use of solar water heaters with electric backup to produce sanitary hot water.
- Sustain the communities power needs by supplying energy to the community locally with distributed generation (thermal in this case), leading to less dependence on the electrical grid.
- Save on costs to heat hot water in the community leading to utility bill savings that remain in the community.

With this vision in mind a feasibility study was undertaken to evaluate the cost/benefit of a number of solar hot water system concepts. A concept (shown in Figure 1) was presented by NRCan / CanmetENERGY to the Pikangikum First Nation Band Council and Eenchokay Birchstick High School principal and construction class teacher, where it was approved for further development. NRCan / CanmetENERGY researchers then worked with university co-op students to design, fabricate, install and test the solar system concept, leading to the development of this Fabrication Plan and Installation Guide.

This Fabrication Plan and Installation Guide is directed at youth and community members who have taken high school level construction class coursework and are comfortable using hand tools.

The solar thermal drainback system, shown in Figure 1 offers a comprehensive opportunity for skills development, including woodworking, plumbing, mechanical and electrical skills.

The solar thermal collectors heat water via a drainback tank with heat exchanger. The closed loop, drainback design eliminates the possibility of freeze-up or overheating because the fluid drains back to the tank when the pumps are off or in the event of a power failure. Installation to ensure the drainback

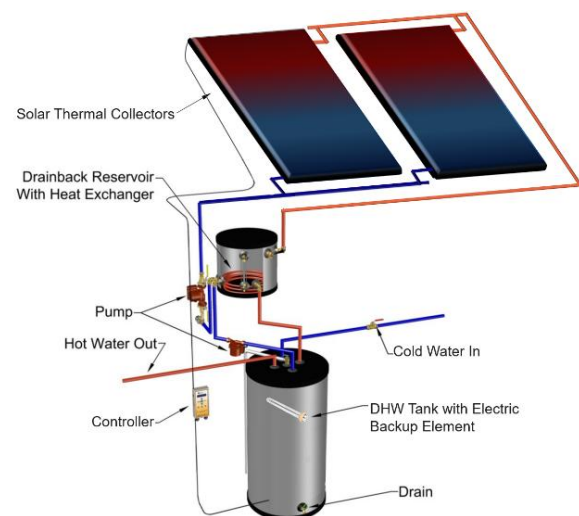


Figure 1: Solar Thermal Drainback System

of the working fluid from the solar collectors back to the drainback storage tank is critical to system functionality.

Overview of the Fabrication Plan and Installation Guide

This document is organized into two parts:

PART 1: Solar Thermal Collector Fabrication Plan

PART 2: Solar Hot Water System Installation Guide

PART 1 provides step-by-step instructions on how to fabricate the jigs, and components needed to build and assemble a full-sized solar thermal collector using commonly available materials, many of which can be sourced locally.

Figure 2 shows an exploded view of the solar thermal collector with the jigs and components labelled with the associated fabrication steps.

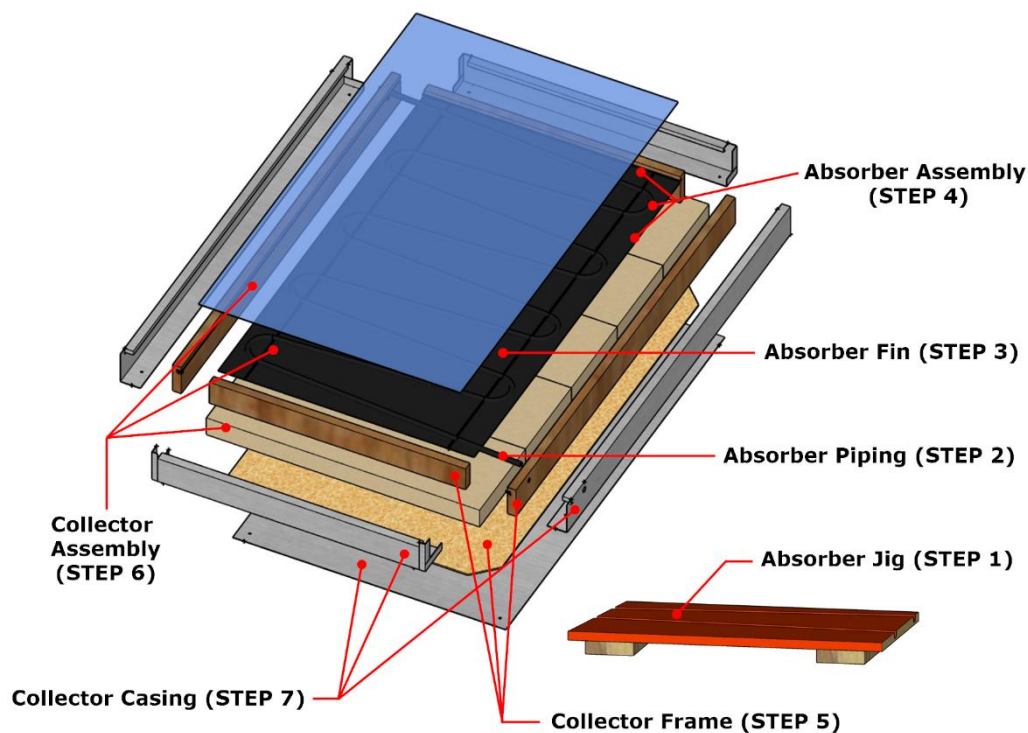


Figure 2: Exploded View of the Solar Thermal Collector Showing Components and Fabrication Steps

Each step in PART 1 is organized as follows.

- A title of the fabrication step and a short description of the task to be completed.
- A list of materials needed to complete the fabrication step.
- A list of tools needed to complete the fabrication step.
- A link to a time-lapsed video demonstrating the completion of the fabrication step.

An image of the completed and fully assembled solar thermal collector is shown in Figure 3.



Figure 3: Completed and Assembled Solar Thermal Collector

PART 2 covers the installation of a typical drainback solar hot water system using the collectors fabricated in Part 1. Topics covered include: collector mounting on a south-facing roof slope or wall of a house; collector header fabrication and distribution piping installation; and balance-of-system installation using components purchased from a solar system supplier.

Each step in PART 2 is organized as follows.

- A title of the installation step and a short description of the task to be completed
- A list of materials needed to complete the installation step
- A list of tools needed to complete the installation step

Additional references and resource materials are listed at the end of this document to provide users with additional information on planning, siting and installation of solar systems.

Personal Protective Equipment (PPE)

Basic personal protective equipment should be worn during the fabrication and installation of the solar thermal collector and solar hot water heating system. This includes:

- Steel-toed work boots
- Safety glasses
- Work gloves
- Dust mask when cutting wood or handling insulation
- Face mask with vapour cartridges when using solvents or paints

Recommended Health and Safety Training

It is recommended that the following basic health and safety training be completed by persons involved in **PART 1, Fabrication** of the solar collectors:

- Workplace Hazardous Materials Information System (WHMIS) training or equivalent as may be required in your jurisdiction or community
- Training on the development of Safety Awareness procedures directed at identifying safety hazards and ensuring control procedures are in place aimed at risk elimination or mitigation
- Training on the use of the tools to be employed in the fabrication procedure including: basic hand tools (hammer, screwdriver, drills, etc.), router, tube bender, table saw, mitre saw, torch and soldering

In addition to the above, persons involved in **PART 2, Installation** of the solar collectors should complete the following health and safety training:

- Fall arrest / working at heights or equivalent training enabling safe installation of roof or wall mounted collectors

PART 1: Solar Thermal Collector Fabrication Plan

STEP1 - Absorber Jig

The absorber jig will be used to fabricate the copper absorber fin. The jig will also aid in the fabrication of the absorber piping and the absorber assembly.

Materials needed:

- Pine shelving (or equivalent), $\frac{3}{4}$ " thick, 20" x 48" (cut to 20" x 36")
- 30" length of 36" width 5 Mil (36 ga.) copper sheet (cut from roll)
- 4' length of 2" X 6" lumber (nominal) cut into two 20" lengths
- #8 $\frac{3}{4}$ " length brass screws (4) to fasten copper sheet to jig
- #8 $1\frac{1}{4}$ " length construction screws (8) to fasten jig to lumber standoffs

Tools needed:

- Square
- Tape measure
- Pencil
- Straight edge (e.g., an angle bar that is long enough to be used as a guide for the router)
- 2 x C-clamps
- Router
- Router Bit, omega profile, $\frac{3}{4}$ " diameter
- Minimum 3' long, $\frac{1}{2}$ " diameter solid steel rod
- Metal snips
- Hammer
- Electric drill or impact tool with screwdriver bit (Robertson #2)

Routing the Grooves in the Jig

Cut the wood shelving to a width 36" to match the width of the copper sheet. Using a square, measure and mark off $4\frac{9}{16}$ " from the top edge of the wood on the left-side, and $2\frac{5}{16}$ " from the top edge on the right-side as shown in Figure 4.

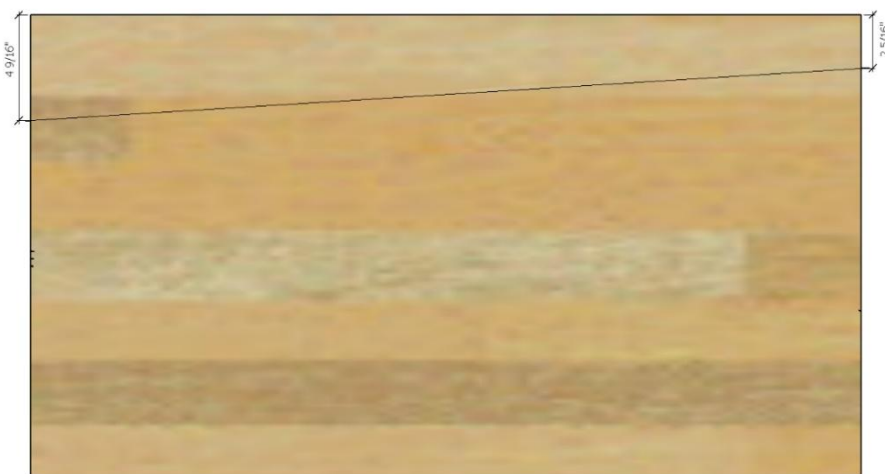


Figure 4: Marking the Centreline Measurements on the Absorber Jig for the First Groove

PART 1: Solar Thermal Collector Fabrication Plan

Draw a straight line between the two measurement points. This represents the centerline of the first groove to be routed into the absorber jig.

Clamp the straight-edge guide onto the absorber jig, with its top edge below and parallel to the centerline marked on the jig as shown in Figure 5. The offset should equal the radius measurement of the router-base being used (i.e., distance from the edge of the router base to the centerline of the router bit). Make sure the C-clamps are on tight as this will be used as the guide when routing out the

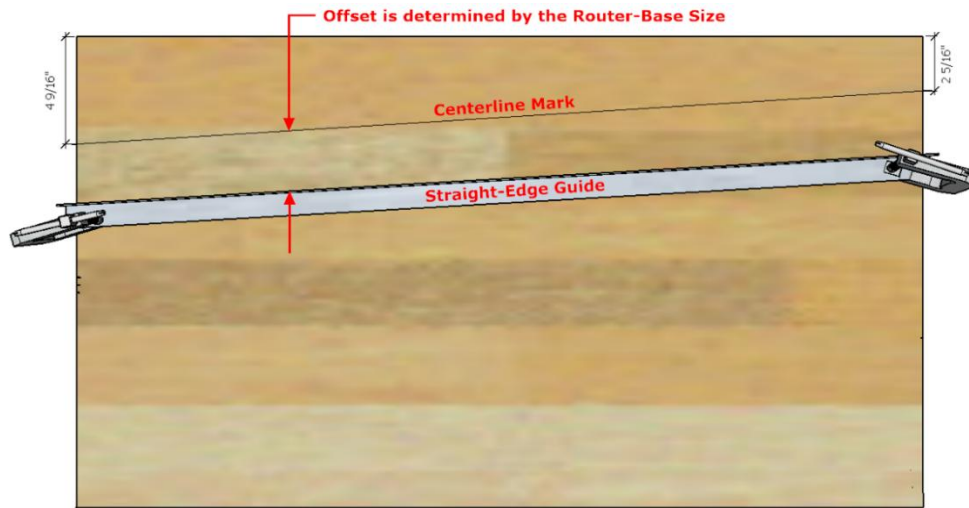


Figure 5: Clamping the Straight-Edge onto the Jig as a Guide for Routing the First Groove

wood, and the bar should not move.

With the 1" omega bit secured in the router, adjust the router to a ½" cutting depth. Run the router through the wood by guiding the router base-plate against the top edge of the guide bar so that the omega bit creates the cut along the centerline mark. You may need to run the router through multiple passes to get the profile needed.

This routing process results in a 1" wide x ½" deep semi-circular groove being cut into the jig as shown in Figure 6.

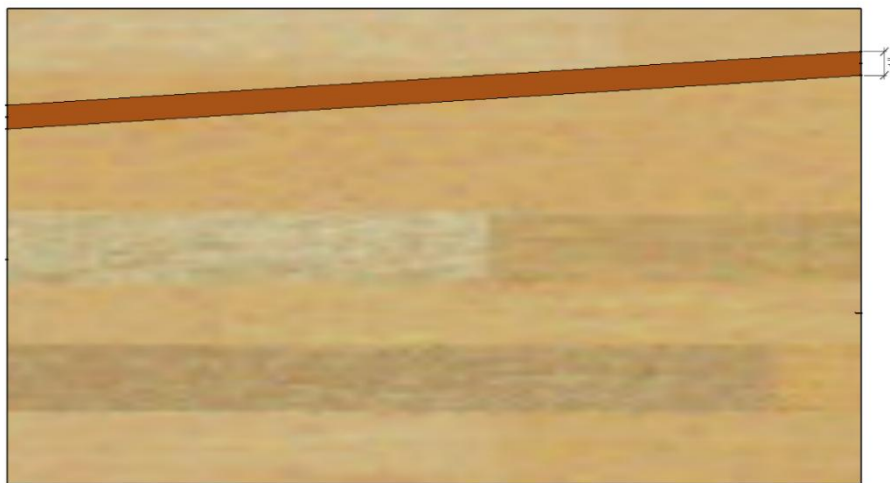


Figure 6: Routing of the First Groove on the Absorber Jig Completed

PART 1: Solar Thermal Collector Fabrication Plan

Now mark the position for the second groove onto the absorber jig as shown in Figure 7. From the bottom edge of the first cut on the left side measure $5\frac{1}{2}"$ and mark it off. On the right side, measure out $10"$ and mark it off. Join the two marks with a straight line. This line will be the centreline for the second groove.

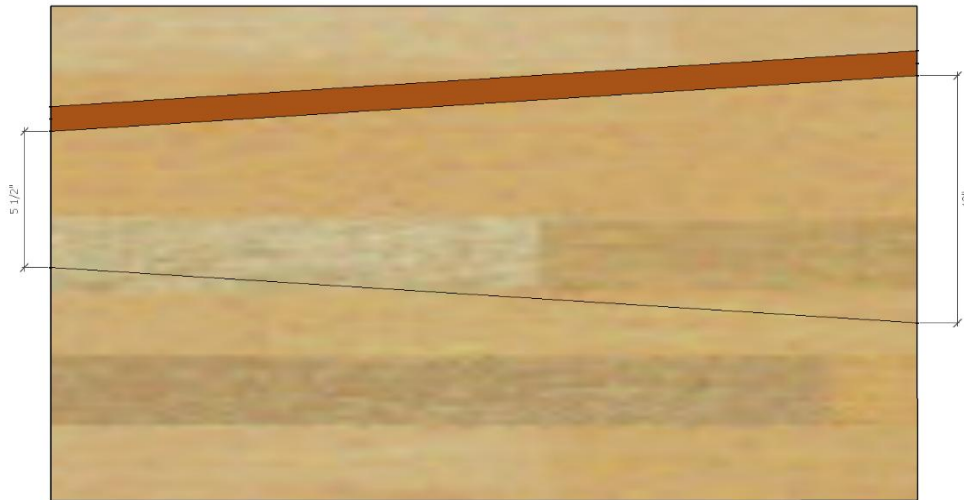


Figure 7: Marking the Centreline Measurements on the Absorber Jig for the Second Groove.

Flip the straight-edge guide over and clamp it to the absorber jig, with its bottom edge above and parallel to the second centerline marked on the jig as shown in Figure 8, using the offset measurement for the router as before.

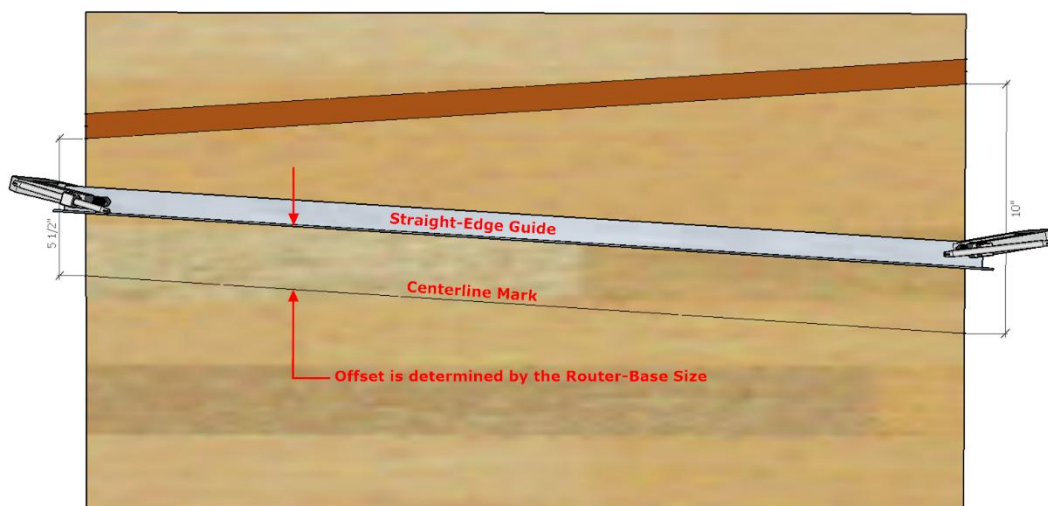


Figure 8: Clamping the Straight-Edge onto the Jig as a Guide for Routing the Second Groove

Repeat the previously used routing process to create the second semi-circular groove, $1"$ wide x $\frac{1}{2}"$ deep along the second centerline mark.

The absorber jig, with the two routed grooves completed, is shown in Figure 9.

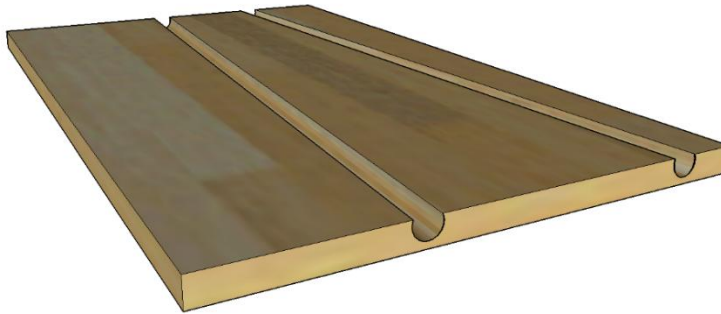


Figure 9: The Absorber Jig, with Two Semi-Circular Grooves Completed

Covering the Jig with Copper

The next step in the fabrication of the absorber jig is to cover the top surface with copper. This will help strengthen the jig so that it can be used for fabrication of many solar collectors. Measure out and cut a 30" long piece of copper from the roll of 36" wide, 5 mil copper sheeting.

Lay the copper sheet on the absorber jig, making sure there is copper hanging over either end of the wood. Clamp the copper sheet down on one side of the jig as shown in Figure 10.

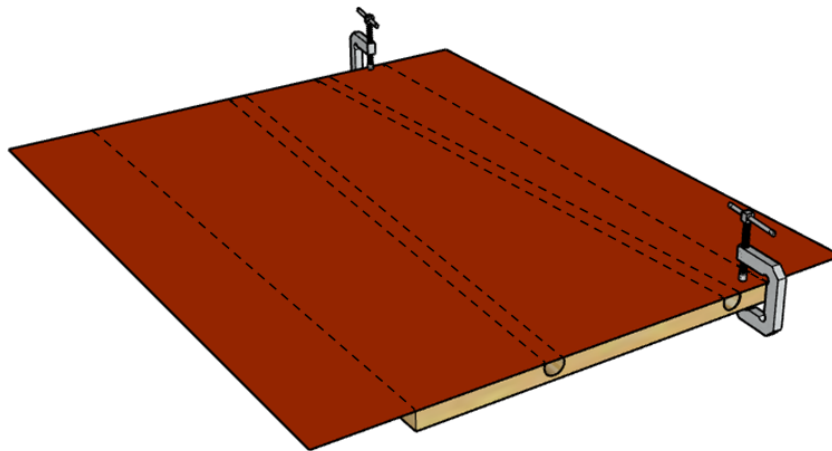


Figure 10: Positioning and Clamping the Copper Sheet onto the Absorber Jig

Using the steel rod, press fit / hammer the copper into the semi-circular grooves, starting with the groove closest to the clamps, so that the copper lines the inside surface of the grooves as shown in Figure 11.

PART 1: Solar Thermal Collector Fabrication Plan

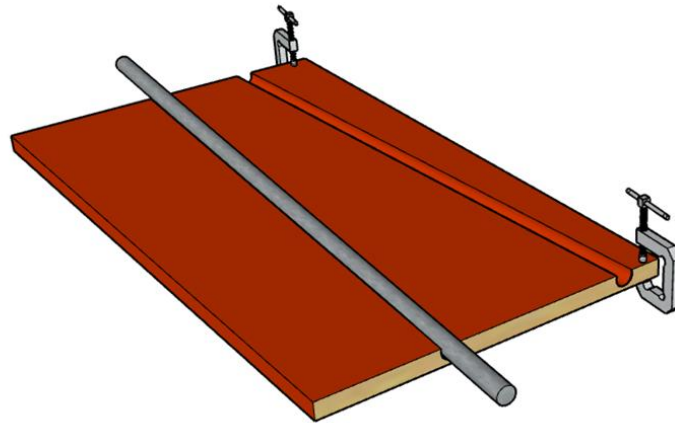


Figure 11: Using a Steel Rod to Press the Copper Sheet into the Absorber Jig Grooves

Secure the copper to the jig by bending the overhanging copper sheet over and under the wood and fasten it to the back of the jig using the $\frac{3}{4}$ " brass screws. The covered absorber jig is shown in Figure 12.

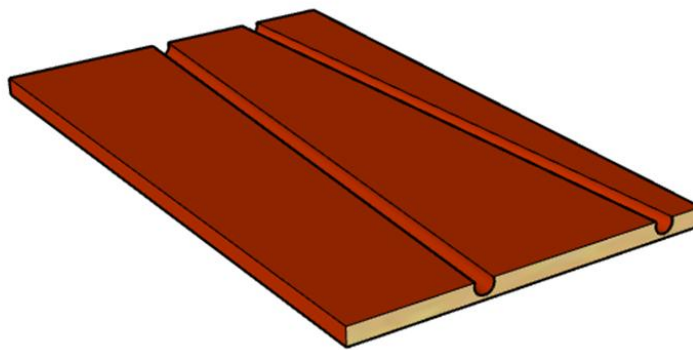


Figure 12: The Absorber Jig covered in Copper Sheet

Lastly, cut the 4' length of 2x6 lumber to two pieces each 20" long (to match the short-side dimension of the jig). Using the 1 $\frac{1}{4}$ " construction screws, fasten the pieces to the bottom outside edges of absorber jig to strengthen it and raise it off the workbench to allow for clamping and tube bending in later steps. As shown in Figure 13, leave about a 2" gap between the outside edges of the jig and the 2x6 standoffs to leave space for clamping.

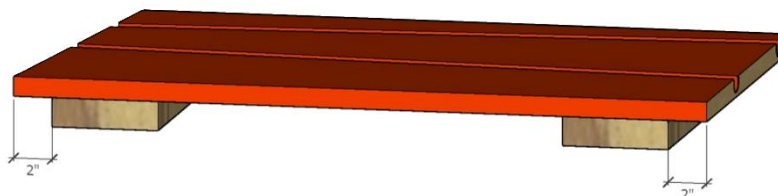


Figure 13: Completed Absorber Jig with Lumber Standoffs

STEP2 - Absorber Piping

The absorber piping is the part of the collector, which absorbs heat from the absorber fins and transfers it to the heat transfer fluid (water).

Materials needed:

- ¾" outside diameter (OD), 3/4" X 50' Air-Conditioning and Refrigeration (ACR) Soft Copper COP Tubing
- Emery cloth

Tools needed:

- | | | |
|--|---|--|
| <ul style="list-style-type: none"> - 2' X 2' X ½" thickness plywood sheet - 1¼" casters, with rubber wheels (4) - #6 5/8" round head wood screws (16) - Reamer / deburring tool - Imperial 600F Worm Gear Tube Bender - 5/8" threaded nut to replace handle on tube (pipe) bender - Hand drill - 11/16" drill socket (or similar, to fit nut on pipe bender) - Tape measure - Tubing cutter (to cut copper tubing) - Permanent marker | } | <p><i>Assemble these components into a Rolling Dolly Platform to support the copper coil</i></p> |
|--|---|--|

This step will require two people assisting each other in the process. It may be useful to practice using the bender first to get familiar with the direction of the bends.

Pipe Coil Rolling Dolly

First, build a pipe coil rolling dolly that will be used to support the coil of copper pipe as it is unrolled during the absorber pipe bending process. Fasten four 1 ¼" caster wheels to the 2' x 2' x ½" plywood sheet using the 5/8" round head wood screws. The rolling dolly will also keep the coil level with the pipe bender as the pipe is fed into the bender.

Preparing the Pipe Bender

Set up the pipe bender by threading the 5/8" nut onto the threaded end of the pipe bender (i.e., replace the hand crank that comes with the bender). The threaded nut will allow a 11/16" drill socket (socket size will depend on the nut used) to work with a hand drill. Use the bender with the ¾" OD mandrel and ¾" OD guide bar.

Making the Pipe Bends

Begin by prepping the end of the copper pipe using the deburring tool and emery cloth.

Roll out a section of the pipe (at least 65") taking care not to kink the pipe as it is unrolled. Place the coil of copper pipe on the rolling dolly with the straight piece of pipe set into the pipe bender.

For the first bend, measure out from the end of the straight piece of the pipe (4') and add an additional 9 ¾" of pipe, for a total measurement of 57 ¾". Place the pipe in the bender, lining up the marked-off measurement with the 0-line mark on the bender, and attach the guide bar to the bender as shown in Figure 14.

PART 1: Solar Thermal Collector Fabrication Plan

Start the bending process by starting up the drill on a low speed, have the second person slowly unroll and move the coiled pipe on the rolling dolly. The coiled pipe will be too heavy for the drill to move it along the table, so the rolling dolly will need to be manually moved along the table to facilitate the bending process. Speed up the drill as the bend starts to take shape, taking care that the copper coil is being supported and the second person is assisting the movement of the coil and dolly.

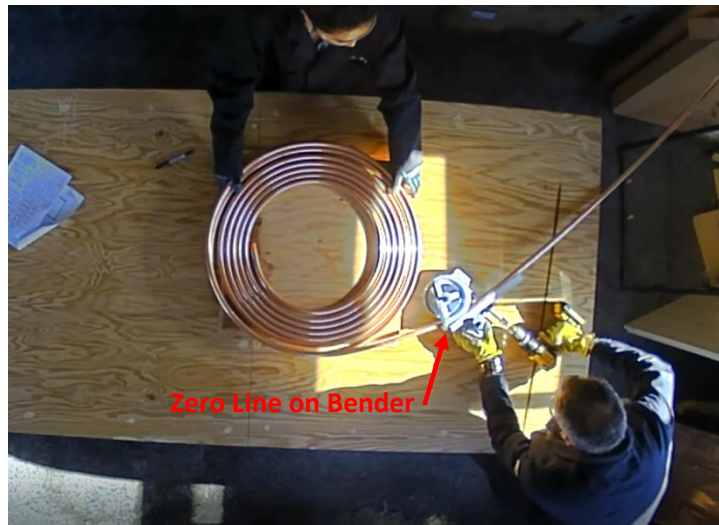


Figure 14: Pipe Bender on the Copper Pipe at the Start of the First Bend

Adjust the position of the pipe bender on the workbench as needed, but do not take the pipe out of the bender until the bend is complete, and keep the pipe level with the coil at all times during the bending process.

Once the desired bend is achieved, over-bend the pipe to about 150° (i.e., a bit beyond the desired bend radius) to compensate for the “spring back” that will take place once the pipe is released from the bender. The absorber jig can be used as a guide to check and adjust each bend to the desired bend radius after the pipe has been removed from the bender as shown in Figure 15.

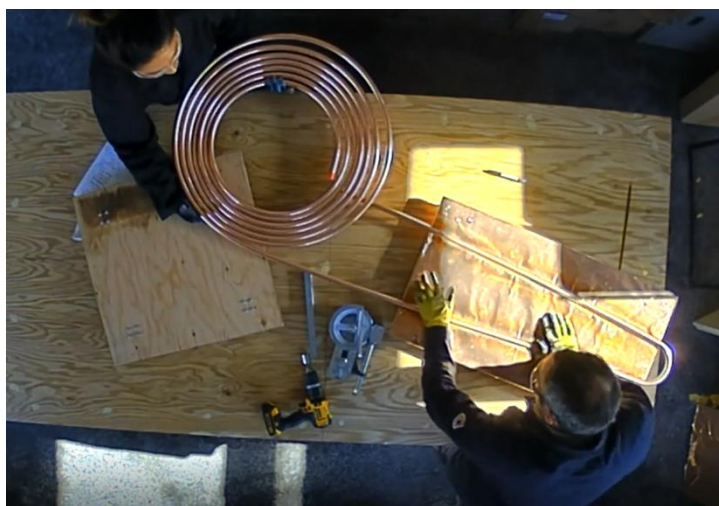


Figure 15: Checking the Bend Radius Using the Absorber Jig

PART 1: Solar Thermal Collector Fabrication Plan

When the bend is complete, remove the bender from the pipe and run the drill in reverse to reset the bending mandrel to the 0-line mark on the bender.

Roll out and straighten more pipe to be able to work with it comfortably. When uncoiling the pipe take care not to kink it. At times, this may require holding the coil upright while a second person unrolls the pipe. **Note:** *The more the pipe gets bent, the harder it will be to uncoil.*

For the second bend, measure out 3' of straight pipe from the end of the first bend, and mark it off.

Since the second bend is made in the opposite direction to the first bend, place the pipe in the bender, with the bender and guide bar facing the opposite direction. Align the 3' mark on the pipe with the zero line on the bender as shown in Figure 16.



Figure 16: Pipe Bender on the Copper Pipe at the Start of the Second Bend

Repeat the bending process. When the bend is complete, remove the bender from the pipe and run the drill in reverse to reset the bending mandrel to the 0-line mark on the bender.

For the third bend, measure 3' 9 ¾" from the end of the last bend. Flip the bender and guide bar around again, and place the pipe in the bender, with the 3' 9 ¾" mark on the pipe aligned with the zero line on the bender.

Repeat the bending process. When the bend is complete, remove the bender from the pipe and run the drill in reverse to reset the bending mandrel to the 0-line mark on the bender.

Continue this process until all the bends are made, alternating both the orientation of the bender and guide bar, and the pipe measurements.

- **Fourth Bend:** 3'
- **Fifth Bend:** 3' 9 ¾"
- **Sixth Bend:** 3'
- **Seventh Bend:** 3' 9 ¾"
- **Eighth Bend:** 3'

PART 1: Solar Thermal Collector Fabrication Plan

Upon reaching the last bend, there will still be coiled pipe left at the end. If needed, roll out and straighten additional pipe to make it workable.

Once the pipe is rolled out, measure out 4' from the end of the last bend and cut it. Prep the end of the copper pipe using the deburring tool and emery cloth.

Additional details on absorber piping dimensions are provide in Figures 17 and 18.

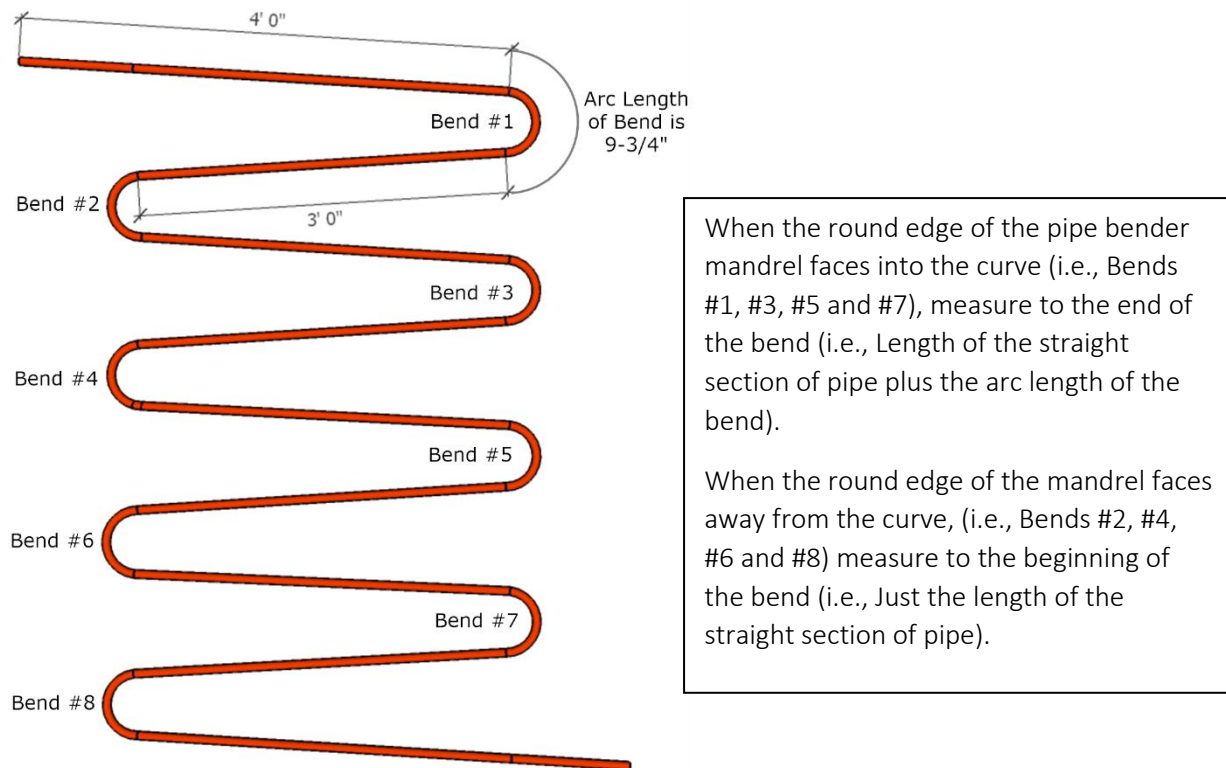


Figure 17: Measurements of the Absorber Pipe Sections

PART 1: Solar Thermal Collector Fabrication Plan

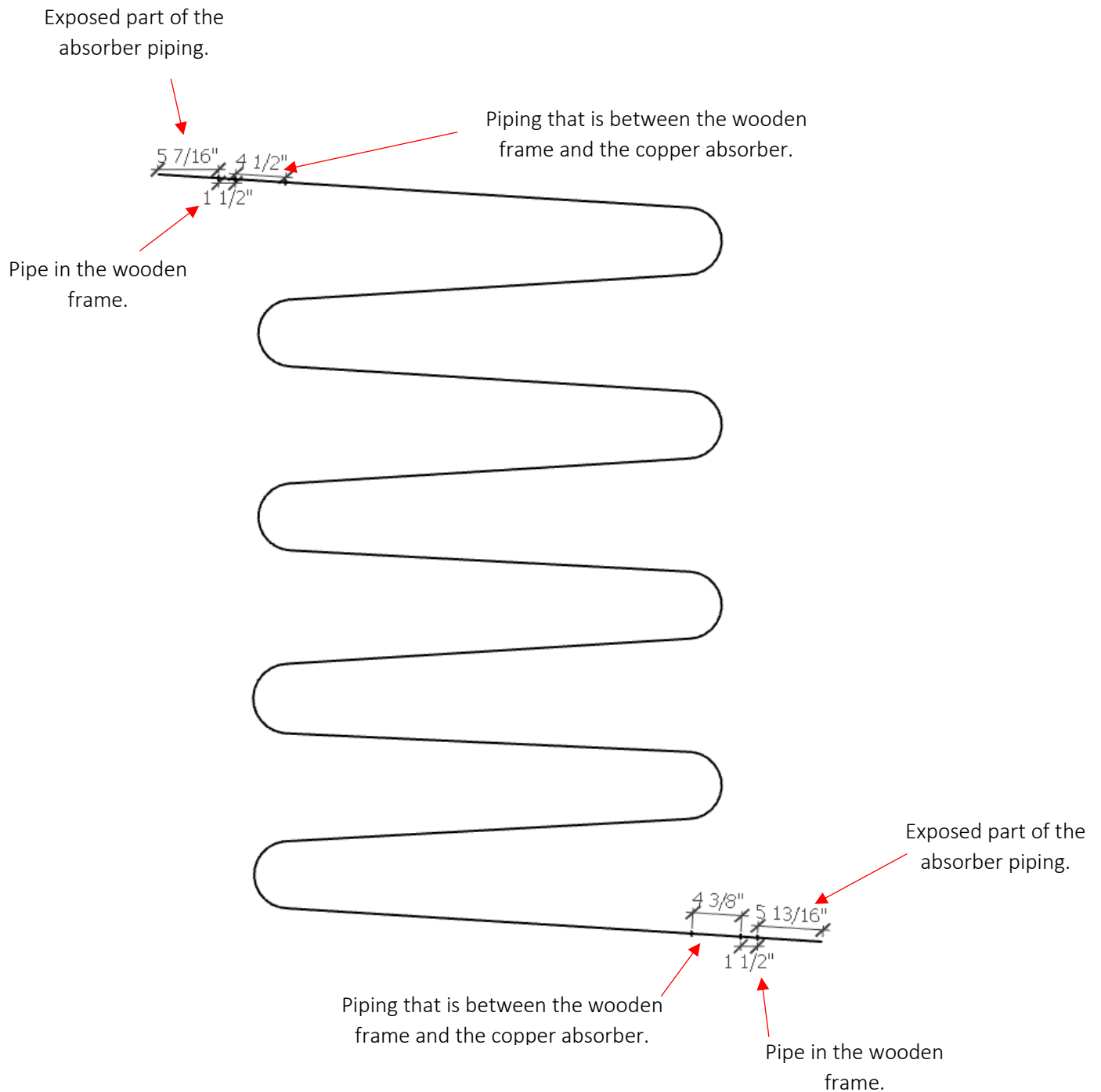


Figure 18: Piping Length Details at the Inlet and Outlet Sections of the Absorber Piping

STEP 3 - Absorber Fin

The absorber fin is the part of the collector which absorbs the sun's heat and transfers it to the absorber piping.

Materials needed:

- 36" X 9' / 10 Mil (30 ga.) Copper Sheet (i.e., half of an 18' roll)

Tools needed:

- Absorber jig
- 2 x C-clamps
- Solid steel rod, minimum 3' long, ½" diameter
- Tape measure
- Metal snips
- Hammer

From the 36" wide copper roll cut off a piece that is 6' 11" long. Reserve the remaining piece of copper sheet for use in STEP 4.

Place the copper sheet centered onto the absorber jig, with the top edge flush with the edge of the jig. Securely clamp the copper sheet down to the top of jig on either side as shown in Figure 19.

NOTE: *This clamping step is important so that during the forming process the copper sheet does not shift which will ensure the dimensions and angles of the formed channels stay uniform.*

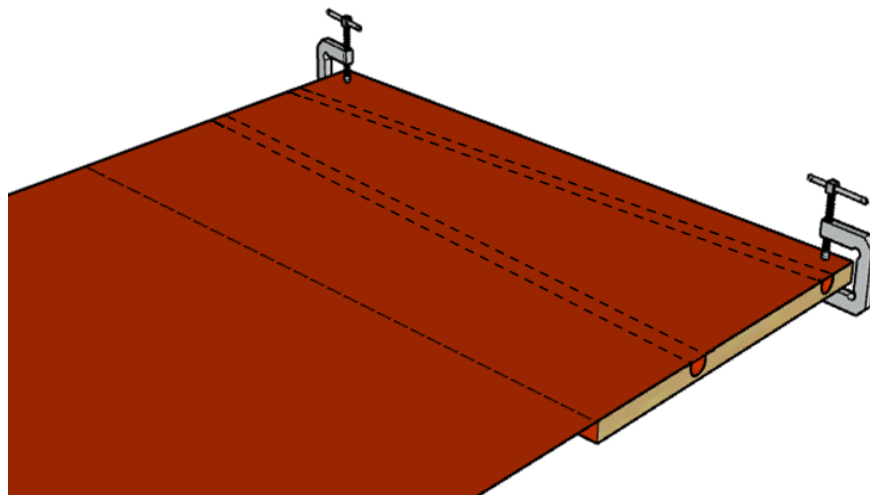


Figure 19: Positioning and Clamping the Copper Absorber Fin onto the Absorber Jig

Starting next to the clamps, place the steel rod on top of the copper sheet aligned with the top groove, as shown in Figure 20, and begin pushing and hammering the steel rod to force the copper sheet into the groove of the absorber jig to form an omega-shaped (Ω) channel in the sheet. Work from side to side to avoid pulling and crinkling the copper sheet. Try to keep the copper fin as smooth as possible.

Having a second person hold the far end of the copper sheet during the process and “flutter” the

PART 1: Solar Thermal Collector Fabrication Plan

sheet up and down while the other person forms the sheet with hammer and steel rod will help allow the sheet to bend freely.

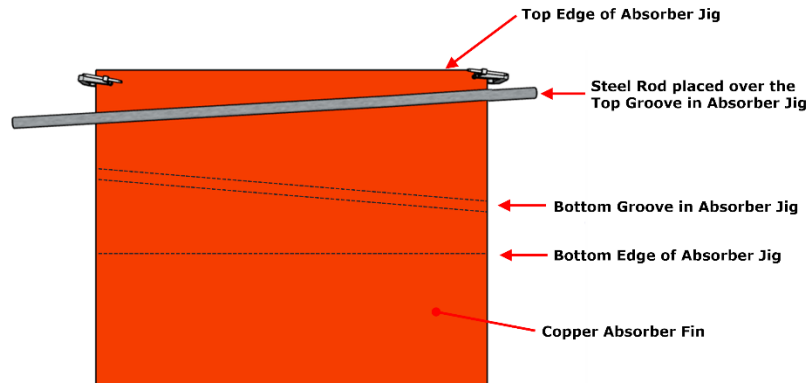


Figure 20: Forming an Omega-shaped Channel in the Absorber Fin using the Absorber Jig and a Steel Rod

Once the first omega-shaped channel has been formed in the absorber fin, repeat the forming process using the bottom groove in the jig.

After the second omega-shaped channel has been formed, unclamp the absorber fin from the jig, rotate the jig 180° under the absorber fin. Shift the copper fin up the jig so that the last omega-channel formed in the fin fits into the top groove on the rotated jig and that the edges of the copper fin are flush with sides of the jig.

Re-clamp the copper sheet in the middle of the jig and repeat the shaping process to form an additional omega-shaped channel using the bottom groove in the absorber jig.

Repeat this process of unclamping the fin; rotating the jig; shifting the fin up; re-clamping the fin; and, form additional omega-shaped channels until a total of nine channels are formed in the copper absorber fin as shown in Figure 21.

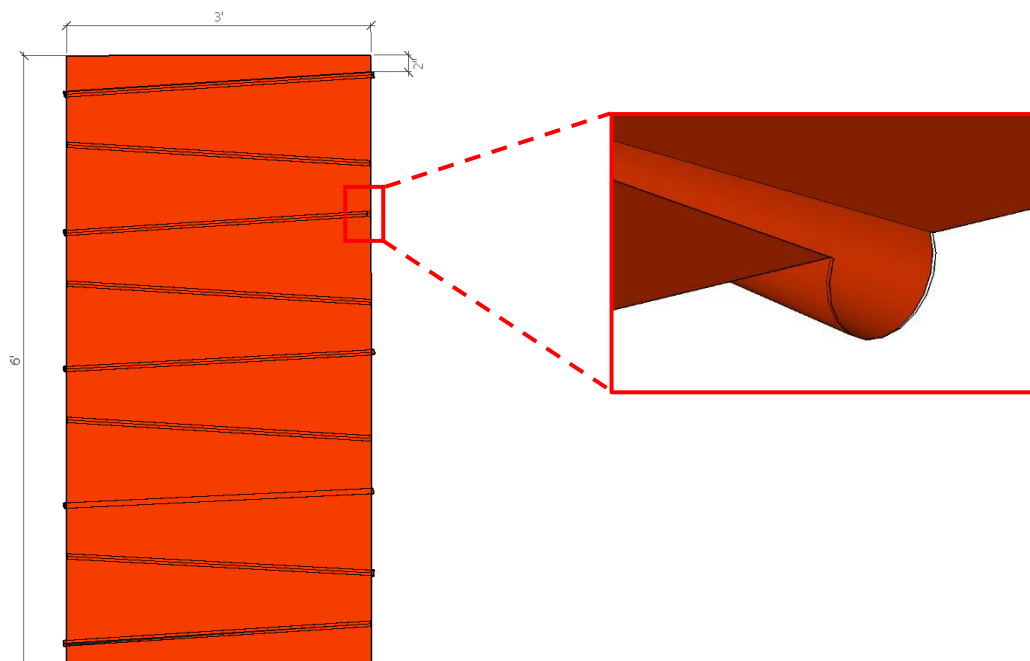


Figure 21: Completed Absorber Fin, with Nine Omega-shaped Channels

STEP 4 - Absorber Assembly

The absorber assembly fits the absorber piping into the absorber fins. Once fitted in, the absorber piping is then soldered to the absorber fins to maximise conduction and close contact between the fin and piping.

Materials needed:

- 95% tin solder
- Soldering paste flux
- Emery cloth
- Copper strapping
- 36" X 25" / 10 Mil (36 ga.) Copper Sheet (left over from STEP 3)
- Solar paint (e.g., ThurmaloX or equivalent)
- Paint thinner (e.g., ThurmaloX or equivalent)
- Paper towel or cloth

Tools needed:

- Propane soldering torch
- Acid brush (for applying solder paste)
- Tape measure
- Hand bender (commonly used to bend metal ductwork)
- Snips
- Hammer
- Flat-blade screwdriver

CAUTION: This step requires the use of a soldering torch.

Ensure there are no flammable items surrounding the work space, that the space is well ventilated, and take care to not harm yourself or others.

PART 1: Solar Thermal Collector Fabrication Plan

Attaching the Absorber Piping

Start the assembly process by placing the top two omega-shaped channels of the absorber fin into the absorber jig for support.

Fit two rows of the absorber piping into the absorber channels. Ensure the spacing on either side of the absorber fin is equal. This should leave a gap between the curved portion of the pipe and the absorber fin of approximately $2\frac{1}{2}$ " on each side as shown in Figure 22.

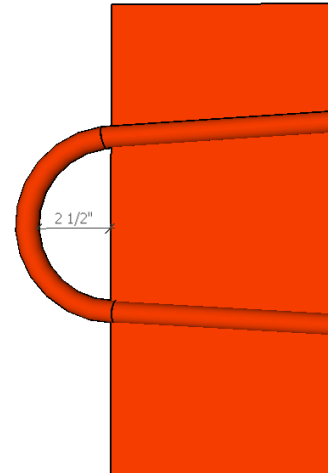


Figure 22: Fitting the Absorber piping into the Absorber Fin

Apply soldering flux along piping where it touches the absorber fin. Clamp the fin and the piping to the jig as shown in Figure 23, taking care not to crush the piping.

Begin soldering one side of the pipe until it has been attached to the absorber fin along its full length. Repeat this for the second side of the pipe.

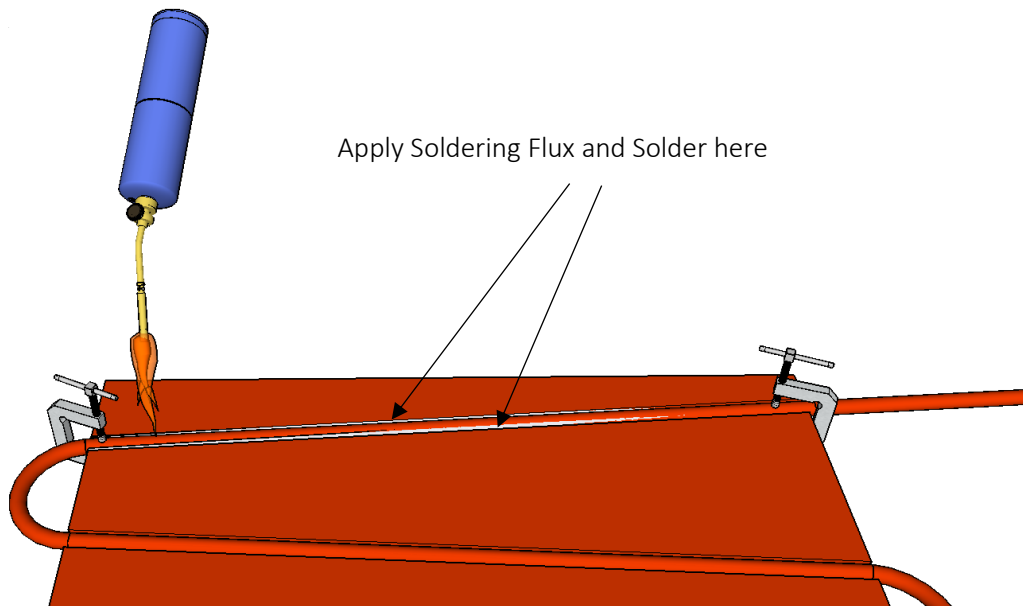


Figure 23: Soldering the Absorber piping to the Absorber Fin

Apply soldering flux along the pipe in the second channel before clamping it down to the jig and soldering the pipe to the absorber fin using the previously described procedure.

Remove the clamps and move the absorber fin up, placing the next two channels into the grooves in the jig. Fit the next two sections of absorber piping, adjusting as necessary to evenly space the pipe bends on either side of the absorber fin.

PART 1: Solar Thermal Collector Fabrication Plan

Repeat all previous steps until all the absorber-fin channels are soldered to the absorber piping as shown in Figure 24.

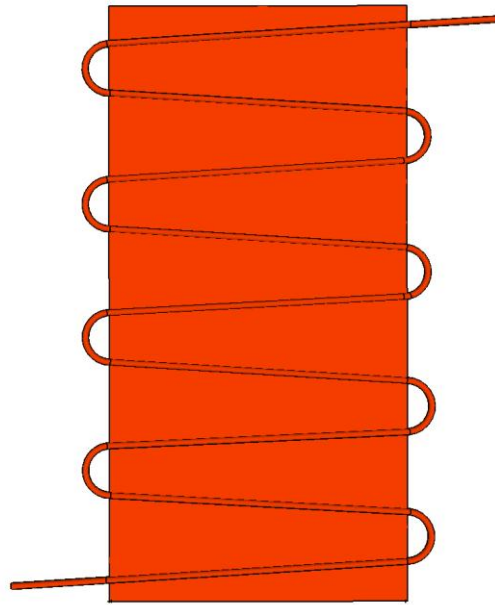


Figure 24: All channels of the Absorber Fin Soldered to the Absorber Piping

Attaching Side Strips to the Absorber

Next, cut out four strips of copper sheet that measure $4\frac{3}{4}'' \times 36''$ as shown in Figure 25 (**Note:** exact width of the strips will depend on the imperfections of the absorber serpentine bends).

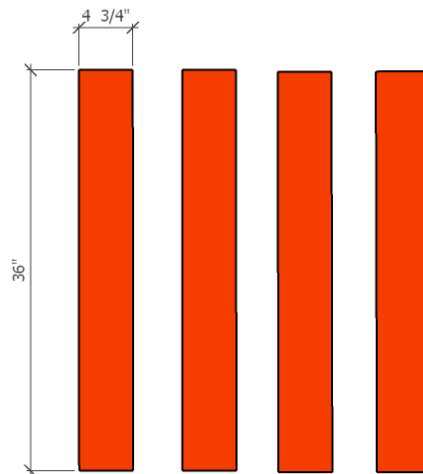


Figure 25: Copper Strips used on the Sides of the Absorber

PART 1: Solar Thermal Collector Fabrication Plan

Flip over the absorber fin-piping assembly so that the soldered channels are facing down and the absorber fin is resting on the work surface.

Position the copper strips (2 per side) under either side of the absorber fin as shown in Figure 26. About 4 ½" of the copper strip will be exposed and ¼" of the strip will be under the main absorber fin. Also overlap the two copper strips by about ¼" at the middle joint on each side of the absorber.

Apply soldering flux underneath the exposed pipe bends, clamp the pipe to the side strip and solder the pipe to the side strip.

Do this for all eight of the pipe bends as well as the inlet and outlet sections of the collector piping.

Next, apply soldering flux to the overlapping areas between the side strips and the main absorber fin and solder the overlapping joints together on the left and right sides of the absorber. You may have to apply downward pressure to ensure the pieces of copper are in contact with each other while soldering.

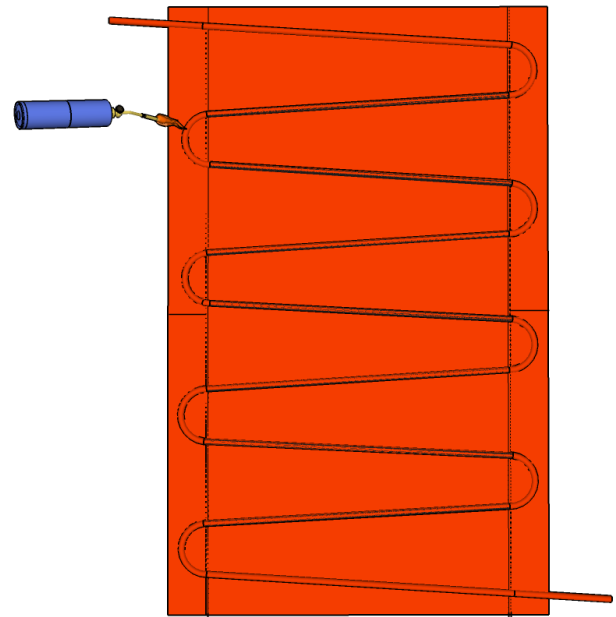
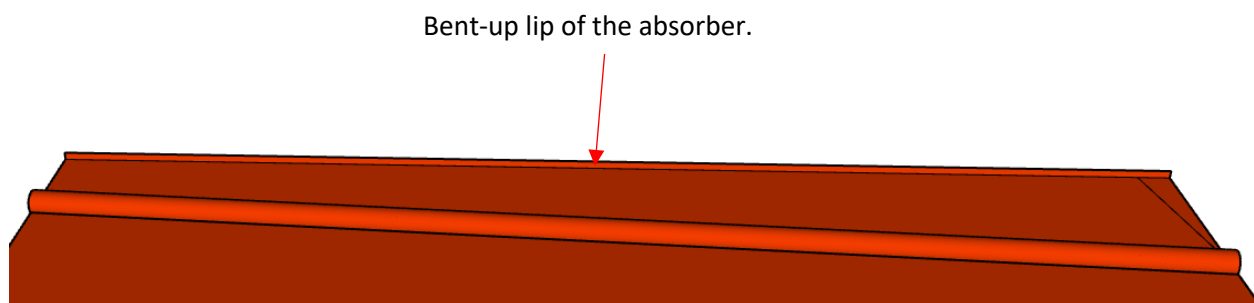


Figure 26: Positioning and Soldering the Copper Side Strips to the Absorber Piping

Finishing the Edges of the Absorber

Using a hand bender, bend up a ½" lip along the top, bottom and both sides of the copper absorber fin as shown in Figure 27. This will stiffen the absorber fin edges and prevent gouging into the thermal insulation during collector assembly.



Bent-up lip of the absorber.

Figure 27: Bent-Up Edge on the Absorber Fin

Attaching Absorber Mounting Straps

Using a hammer and flat-blade screwdriver, punch slots through the copper sheet to install copper strapping which will secure the absorber assembly to the wooden frame of the collector. Punch 12 slots at the locations shown in Figure 28. There are:

- Two slots at the top,
- Two slots at the bottom,
- Eight slots on the sides, one inside each pipe bend.

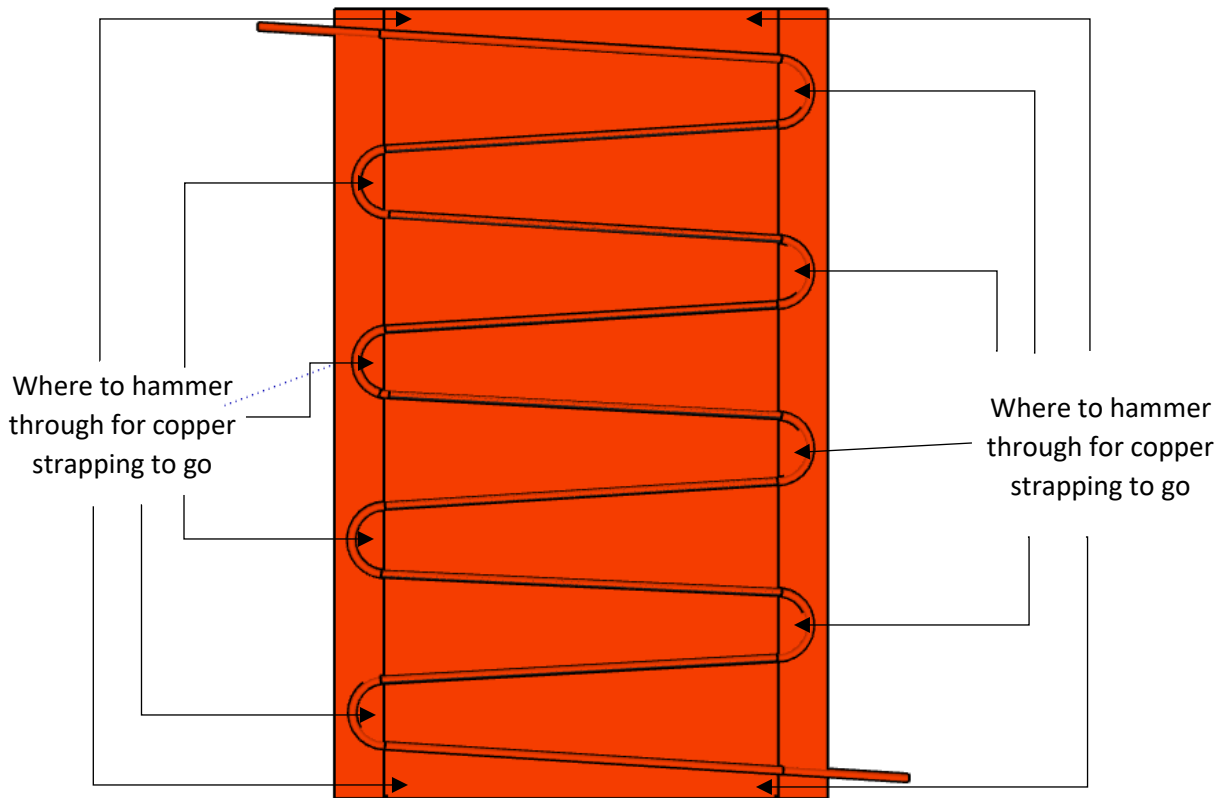


Figure 28: Locations for Attaching Copper Strapping to the Absorber Assembly

For the top and bottom holes, cut a least 6" piece of copper strapping. Thread the strapping through the holes in the absorber fin, folding it onto itself, and solder to the absorber fin, ensure that there is enough strapping overhanging the edge of the absorber for attaching to the frame.

For the holes at the piping bends, cut a 8" piece of copper strapping. Thread the strapping through the holes in the absorber fin and around the pipe, and soldering them just like the top and bottom straps.

*PART 1: Solar Thermal Collector Fabrication Plan****Painting the Absorber***

Refer to the directions on the paint can for specific instructions related to surface preparation and paint application.

Prepare and clean the top surface of the absorber sheet and exposed piping following the manufacturer's instructions.

Apply an even coat of solar paint to the absorber sheet and exposed parts of piping. Try to keep the application of paint to one coat, and spray it evenly.

The completed absorber assembly is shown in Figure 29.

WARNING: After painting be very careful with handling the absorber as the paint chips and scratches easily.

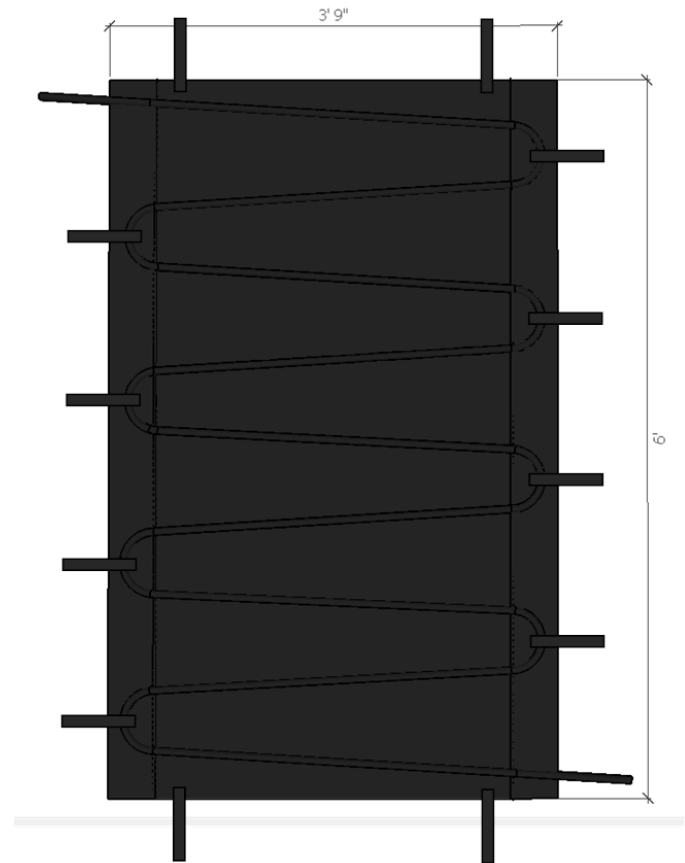


Figure 29: The Completed Absorber Assembly Coated with Solar Paint

CAUTION: The use of paint thinner and paint will release noxious fumes.

Ensure the workspace is well ventilated and use a half-face mask with organic cartridges and goggles or full-face mask with organic cartridges.

STEP 5 - Collector Frame

Used as the structural component for the collector. Wood framing is used to hold glass in place.

Materials needed:

- 3 x 2" x 6" (nominal) x 8' Lumber pieces
- 1 x 4' x 8' x 1/4" OSB Sheet
- 8 x Wood screws (#8 Robertson head, 3" length)
- 40-50 x Wood screws (#8 Robertson head, 3/4" length)

Tools needed:

- Drill
- Bit set
- Miter saw with stand
- Table saw and stand
- Jigsaw with wood blade
- #2 Robertson screwdriver (Red)
- Tape measure
- Pencil

Collector Frame

Cut the 2" x 6" lumber to two pieces at 76 1/2" length, and two pieces at 45" length.

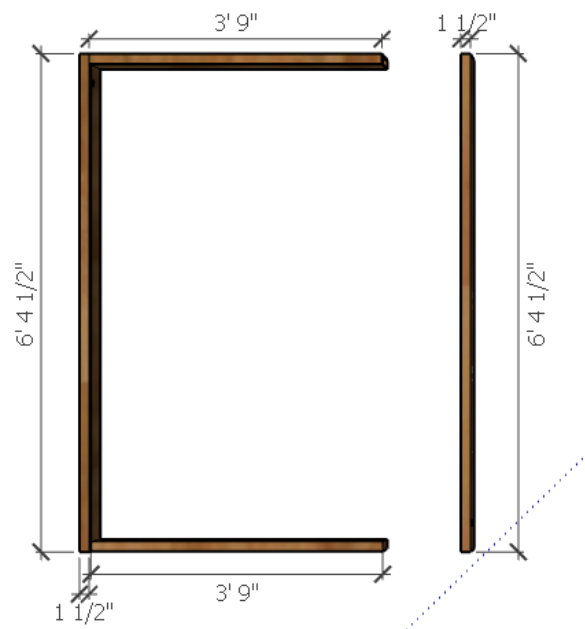


Figure 30: Cutting the Collector Frame Pieces to Length

In this step, you will be notching the lumber to enable the glass to slide into these notches. Set-up the table saw so the blade height will create a 1/2" cut depth. Have the table saw's guide set up so that it will cut 3/4" in from the edge of the lumber (refer to Figure 31). Measure the glass thickness and ensure the notches are cut about 1/8" wider than the width of the glass to allow for the glass to fit snug into the notched lumber (in this case, the glass is 1/8" width, so the notches will be cut 1/4" wide).

PART 1: Solar Thermal Collector Fabrication Plan

Measure the table saw's blade width as the blade width will determine the width of the first cut of the notch.

Run all four pieces of lumber through the table saw twice, to ensure the notches are deep enough.

For example, if the table saw blade width is $\frac{1}{4}$ " then the lumber will only need the previous steps. If the table saw's blade width is narrower than $\frac{1}{4}$ " then the guide will need to be moved and the lumber pieces run through again (twice each) to achieve a $\frac{1}{4}$ " notch width. Depending on the blade width, move the guide accordingly to create a $\frac{1}{4}$ " wide notch.

If a second cut needs to be made, ensure that the top of the notch remains at $\frac{3}{4}$ " from the top of the lumber as shown in Figure 31. Notching a little bit wider than $\frac{1}{4}$ " (example $\frac{3}{8}$ ") may be helpful to allow for glass to slide into the collector frame as described in Step 6, but ensure the notch remains $\frac{3}{4}$ " from the top of the lumber and that it is cut equally for all four wood pieces.



Figure 31: Location and Dimensions of the Notch Cut into the Collector

Once all the notches are made adjust the blade height of the table saw to a 2" cutting depth. Keeping the guide in the same spot, take one of the 45" long pieces and run it through the saw so that the strip of wood is trimmed off above the notch leaving a piece of wood with a width of about $4\frac{1}{2}$ " as shown in Figure 32. This narrower piece of wood will form the bottom edge piece of the collector frame.

PART 1: Solar Thermal Collector Fabrication Plan



Figure 33: Piece of Wood Used for the Bottom-edge of the Collector Frame

Using the 3" long wood screws, fasten the two 45" pieces of lumber to one of the long (76.5") pieces of lumber as shown in Figure 33.



Figure 32: Three sides of the Collector Frame Assembled

Ensure the grooves in the top and side pieces are facing inward and line up with each other before fastening. Ensure that the top-edge of the narrower piece of lumber, used at the bottom of the collector frame, lines up with the bottom-edge of the groove on the long side-piece before fastening. Once assembled, the three sides will form the sub-assembly shown in Figure 34.

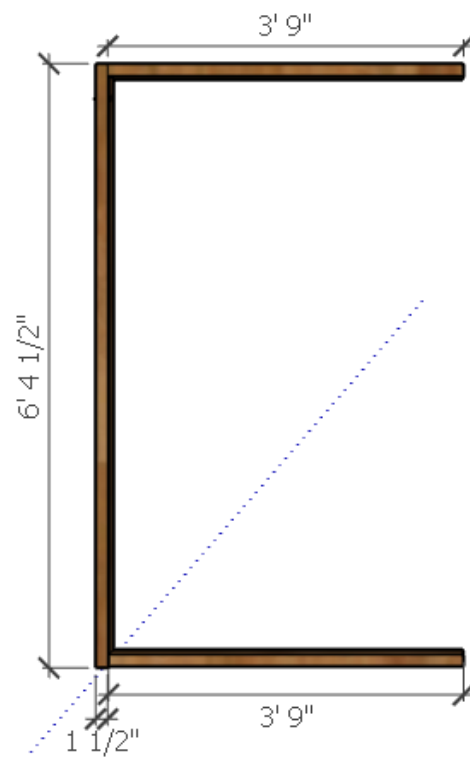


Figure 34: Attaching the Top and Bottom Frame Pieces to One of the Side Pieces

PART 1: Solar Thermal Collector Fabrication Plan

Collector Back Panel

Cut the OSB sheet to a size of 48" x 76.5" (i.e., trim 19.5" from the end of the sheet) using a jigsaw. This OSB sheet will form the back panel of the collector frame.

On each corner of the OSB panel measure 4" along each edge as shown in Figure 35.

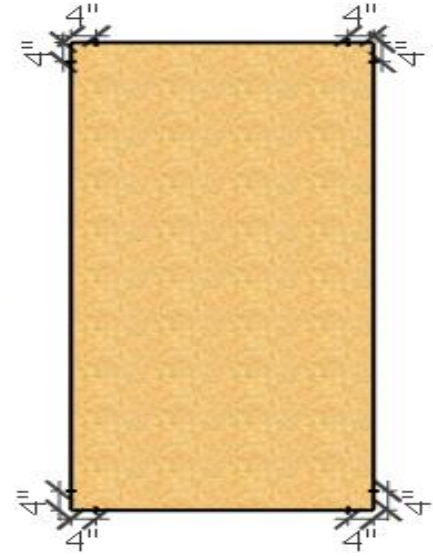


Figure 35: Cutting the OSB Back Panel to Size and Marking the Corners

Using a jigsaw, make a diagonal cut between the 4" markings at each corner of the OSB panel as shown in Figure 36.

Do this for all four corners of the back panel. These notches will allow for collector to “breathe” as may be needed to rid the collector of moisture should humid air condense on the inside surface of the collector glass from time to time.

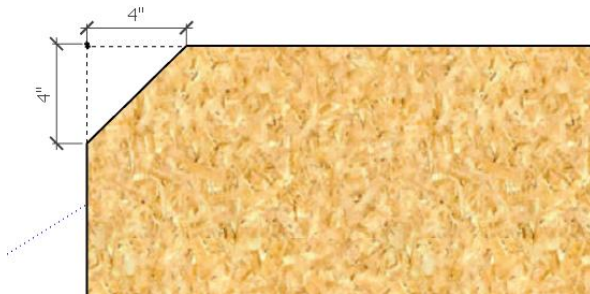


Figure 36: Cutting Off the Corners of the Back Panel

The completed back panel is shown in Figure 37.

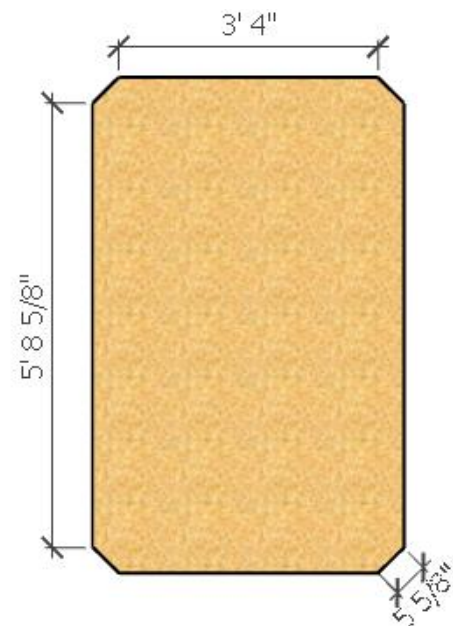


Figure 37: Final Dimensions of the Collector Back Panel

PART 1: Solar Thermal Collector Fabrication Plan

Collector Box Assembly

Position the three sides of the assembled collector frame on the workbench with the notches in the side and top pieces nearest the workbench surface.

The narrower piece lumber, forming the collector-frame bottom-edge, will leaving a gap. Use a scrap of wood about 1" thick to support the free end of the bottom edge piece so it is parallel with the workbench surface.

Test fit the fourth side of the collector frame, ensuring the notch is facing inward and aligns with the notch in the top-piece of the frame.

Place the OSB back panel onto the frame with the smoother side of the OSB board facing down as shown in Figure 38. Make sure there is an opening (for drainage) between the inside of frame corners and the OSB sheet where the diagonal cuts were made.

Using the OSB edges as a guide, line up the collector frame sides and square the frame.

Once the frame is square, fasten the outer edges of the OSB back panel to the collector frame using $\frac{3}{4}$ " wood screws, spaced about 6" apart, making sure the screws are aligned with the middle of the wooden frame pieces. Do this for the three collector-frame pieces that are attached to each other. The fourth side piece is left unattached to facilitate the insertion of thermal insulation and absorber piping in STEP 6.

The assembled collector frame is shown in Figure 39.

Note: The holes for the absorber pipes will not be drilled yet.

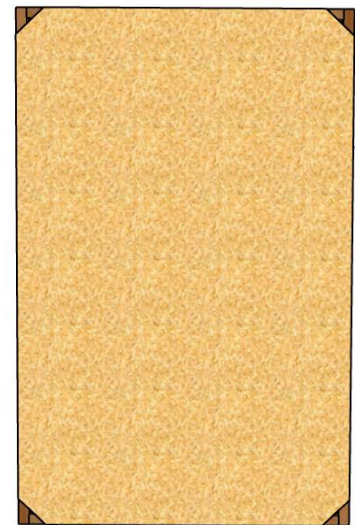


Figure 38: Attaching the Back Panel to the Collector Frame

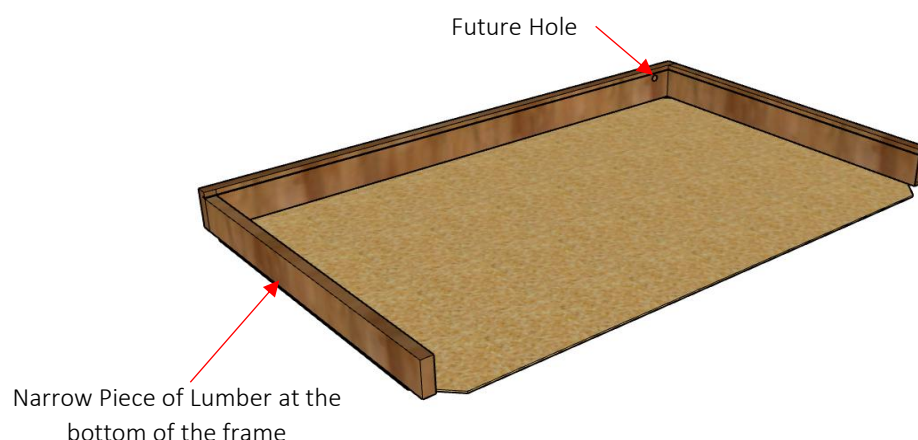


Figure 39: View of the Wooden Collector Frame After Assembly with One of the Side Pieces Unattached

STEP 6 - Collector Assembly

Materials needed:

- Rockwool R14 insulation batt 16" wide for 2x4 studs (or equivalent)
- Silicone gasket weather stripping (silicone can withstand high temperatures)
- Electrical tape
- Brass or copper screws (#8 Robertson head, 1" length)
- Silicone caulking
- 4 mm (1/8") Tempered glass panel 46" x 76"

Tools needed:

- Electric drill
- 1" Hole saw
- Caulking gun
- Utility knife
- #2 Robertson screwdriver (Red)
- Tape measure

This step will need at least two people to work together to complete as the glass glazing is heavy and difficult to manipulate into place. Three people are beneficial for the step of inserting the glass.

Collector Insulation

The insulation comes in strips with the measurements shown in Figure 40.

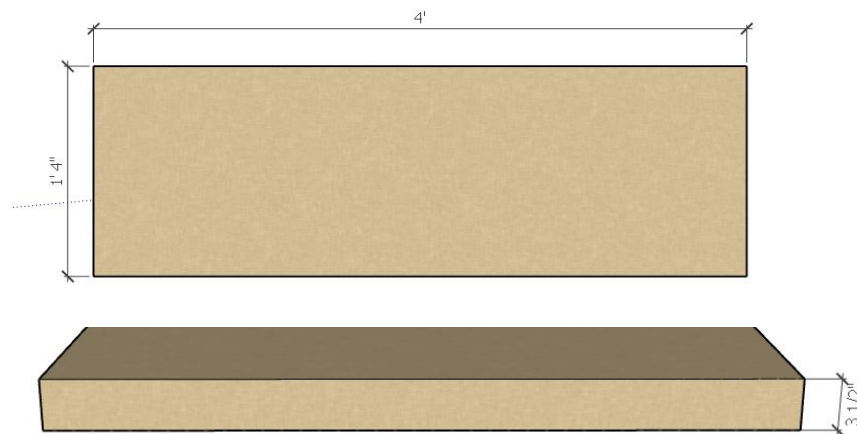


Figure 40: Insulation Batt Dimensions

Lay strips of insulation into collector frame. Take care not to rip or tear the insulation when handling and sliding it into the collector frame.

While laying the insulation, press down on the pieces to compress them down into the collector frame. This will help the absorber lay further down into the collector and prevent the absorber from touching and scratching the glass.

PART 1: Solar Thermal Collector Fabrication Plan

Once there are 4 strips of insulation in the frame, compress and squeeze the insulation from side to side so that a 5th strip of insulation can be squeezed in as shown in Figure 41. Trim back the insulation with a utility knife as needed to ensure it fits snug and flat, with no bulges.

Finally, test fit (but do not attach) the fourth side of the frame on the open side of the collector box and trim the excess insulation using a utility knife to ensure a snug fit with no bulges, with the side piece in place.

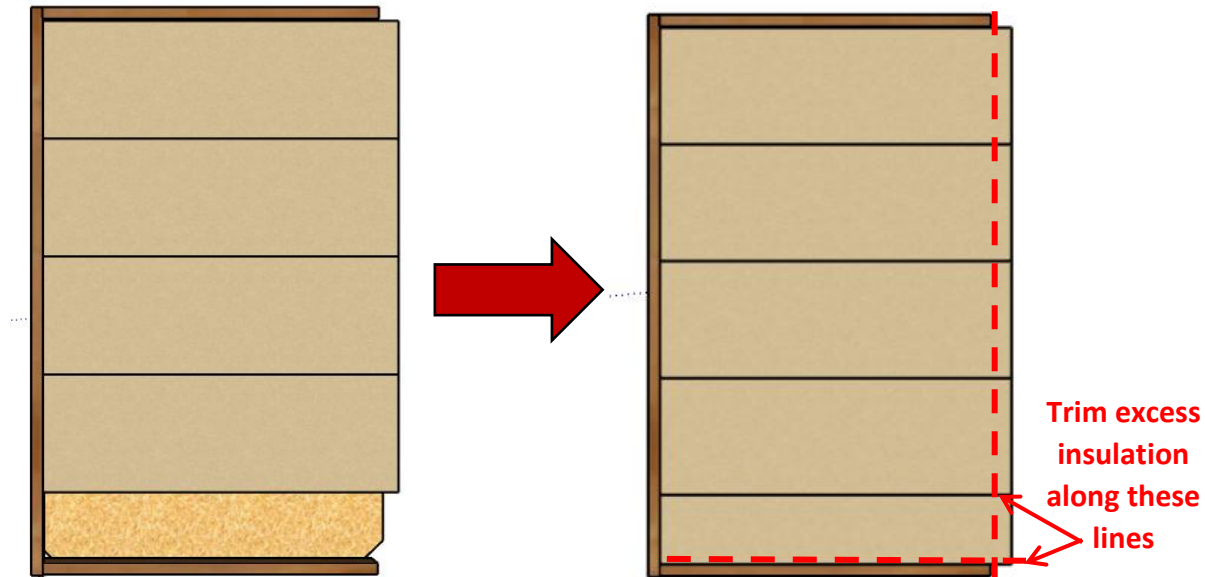


Figure 41: Installing and Trimming the Five Strips of Insulation in the Collector Frame

Adding the Absorber

Once all the insulation has been placed into the frame, press down on the tops of the insulation. Lay the completed absorber assembly on top of the insulation. Trace out on the lumber where the pipe should protrude out on the left-side of the collector frame.

Mark and drill a 1" (D) hole on the attached piece of lumber using a hole saw. The hole's centre will be approximately 4-5/16" from the side and 1-5/8" from the top of the lumber as shown in Figure 42. Be sure to drill the hole at the same angle as the pipe exiting the absorber assembly.

Wrap the part of the pipe that will be contacting the wood with silicone weather stripping and electrical tape. Use the electrical tape on each end of the wrapped weather stripping to hold it onto the pipe.

Feed the absorber pipe through the hole and place the absorber in the collector frame and centre it in the frame.

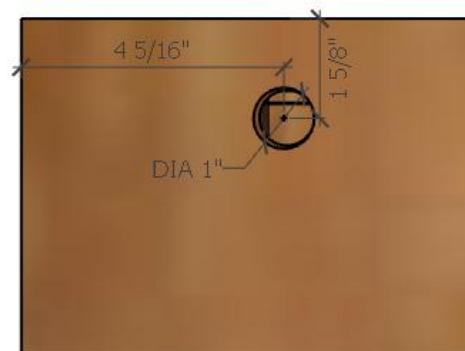


Figure 42: Location of Hole to be Drilled in the Collector Frame for the Absorber Pipe

PART 1: Solar Thermal Collector Fabrication Plan

Take the remaining side piece and line it up with the collector frame and mark the location of the second absorber pipe. Repeat the drilling process for the hole on this piece of lumber. Make sure to wrap the part of the pipe that will contact the wood with silicone weather stripping and electrical tape as described previously.

PART 1: Solar Thermal Collector Fabrication Plan

Once the second hole has been drilled, feed the absorber piping through the collector side piece of wood and fasten the side piece to the rest of the frame using 3" screws. Then attach the remaining side of the back panel to the frame using $\frac{3}{4}$ " screws.

Next, fasten the twelve straps extending from the absorber assembly using brass or copper screws to the inside of the wooden frame. When screwing the straps into the frame, insert the screws at a downward angle to keep the absorber pushed down on the insulation and to ensure space is left between the absorber and the glass panel. The resulting absorber sub-assembly is shown in Figure 43.

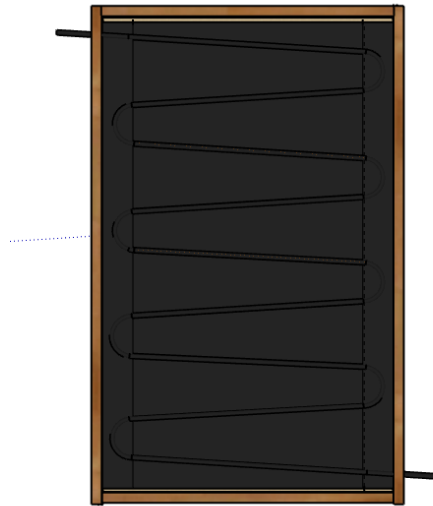


Figure 43: Absorber Assembly Mounted in the Wooden Collector Frame

Installing the Collector Glazing:

Starting from the bottom of the collector frame, slide the glass panel, shown in Figure 44, into the notches in the frame. The glass measures to be 76" x 46" and $\frac{1}{8}$ " thick and should slide into the $\frac{1}{4}$ "

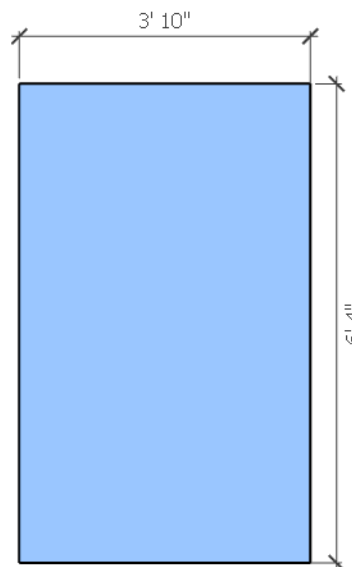


Figure 44: Glass panel used to glaze the Solar Collector

PART 1: Solar Thermal Collector Fabrication Plan

notches in the frame. Having one person hold the far edge of the frame while another slides the glass into the notched frame will be needed. Having a third person to help start the process would be ideal.

Once inserted into the frame, the glass should extend beyond the edge of the wood by about $\frac{1}{2}$ " at the bottom edge of the collector as shown in Figure 45. This forms a drip edge, which will help prevent water from seeping into the collector box.

An aluminum edge piece will be installed in STEP 7 to seal the glass to the frame.

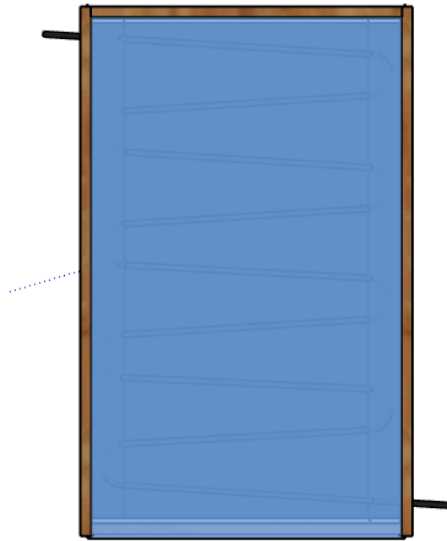


Figure 45: Glass Panel Inserted into the Notches of the Collector Frame

Complete this step in the assembly process by sealing around the two pipes protruding through the holes in the frame with silicone caulking.

STEP 7 - Collector Casing

The aluminum casing will protect the wooden frame from weather conditions and general wear and tear.

Materials needed:

- 12"x 50' Aluminum flashing
- 4'x 8' Aluminum sheet
- Aluminum screen for insect protection
- Aluminum trim nails
- Stainless steel screws (or aluminum nails with pre-drilled pilot holes can be used)
- Nylon washers
- Clear silicone caulking

Tools needed:

- Bending brake (ideally equipped with a cutter)
- Hand bender
- Electric drill
- 1" Hole saw
- Metal snips
- Utility knife
- Rubber mallet
- Tape measure
- Permanent marker
- Caulking gun

This step will need at least two people to work together to complete as the flashing pieces will be long.

It may be useful to practice using the bending brake on scraps of metal flashing before proceeding with this step.

Flashing Preparation:

Roll out the flashing on the work bench, have one person hold one end of the roll to prevent the roll from rolling off the table. Measure 6'-7 ½" and mark it off using a permanent marker on either side of the flashing, then roll the flashing back up to make it easier to carry.

Carry the flashing to the bending break, and have the person holding the roll of flashing position themselves behind the bender. Open the jaw of the bender and feed the flashing from the back and through the front of the bender. Feed the flashing through until the 6'-7 ½" marks show up. Line up the markings to the edge of the bender, making sure both sides are lined up with the edge of the bender when the bender clamps down (to ensure a straight cut).

Take the utility knife and run it along the flashing a few times to score a straight line, using the edge of the bender as a guide. It is important that the line is straight so that the cut is straight.

Lift the arm of the bender and then bend the flashing back down with your hands, and repeat until the flashing snaps off at the scored line. Some bending brakes are equipped with a cutter on rollers, making this process much easier.

Repeat these steps for another 6'-7 ½" piece and then two pieces measuring 4'-3".

PART 1: Solar Thermal Collector Fabrication Plan

The 6'-7 ½" pieces are for the sides of the collector, and the 4'-3" are for the top and the bottom of the collector.

For the side pieces (2 x 6'-7 ½") and the top piece (1 x 4' 3"), measure out the following dimensions for bends on the flashing:

- From the long edge measure and mark off ½".
 - This will go on top of the glass into the groove.
 - Insert the flashing into the bender, with the ½" piece sticking out of the front of the bender. Ensure the measurement of the flashing is straight on the bender. Raise the arm of the bender to create a 90° bend on the flashing.
- From the previous bend measure and mark off ¾" and add 1/16" to the measurement¹² (i.e., total of 13/16").
 - This will go on top of the glass and cover the lip of the collector's frame.
 - Insert the flashing into the bender, with the ½" and ¾" pieces sticking out of the front of the bender. Ensure the measurement of the flashing is straight on the bender. Raise the arm of the bender to create a 90° bend on the flashing.
- From the previous bend measure and mark off 1½" and add 1/16" to the measurement. (i.e., total of 1-9/16")
 - This will go on top of the collector.
 - Insert the flashing into the bender, with the previous bends sticking out of the front of the bender. Ensure the measurement of the flashing is straight on the bender. Raise the arm of the bender to create a 90° bend on the flashing.
- From the previous bend measure and mark off 5-3/4" and add 1/16" to the measurement. (i.e., total of 5-13/16")
 - This will cover the side of the collector.
 - Insert the flashing into the bender, with the previous bends sticking out of the front of the bender. Ensure the measurement of the flashing is straight on the bender. Raise the arm of the bender to create a 90° bend on the flashing.
 - There should be approximately 3 ½" of aluminum remaining after this bend. This remaining length will be covered by the aluminum sheet that will cover the back of the collector frame.

Note: When measuring the location of the bends, double check the measurements on the collector's frame to validate the given measurements. When measuring the collector's framing, do not forget to account for the thickness of the OSB panel attached to the back of the collector frame.

¹² **Note:** The extra 1/16" added to the measurements allows the aluminum bends to fit comfortably around the wooden frame.

PART 1: Solar Thermal Collector Fabrication Plan

The resulting profile for these bends is shown in Figure 46.

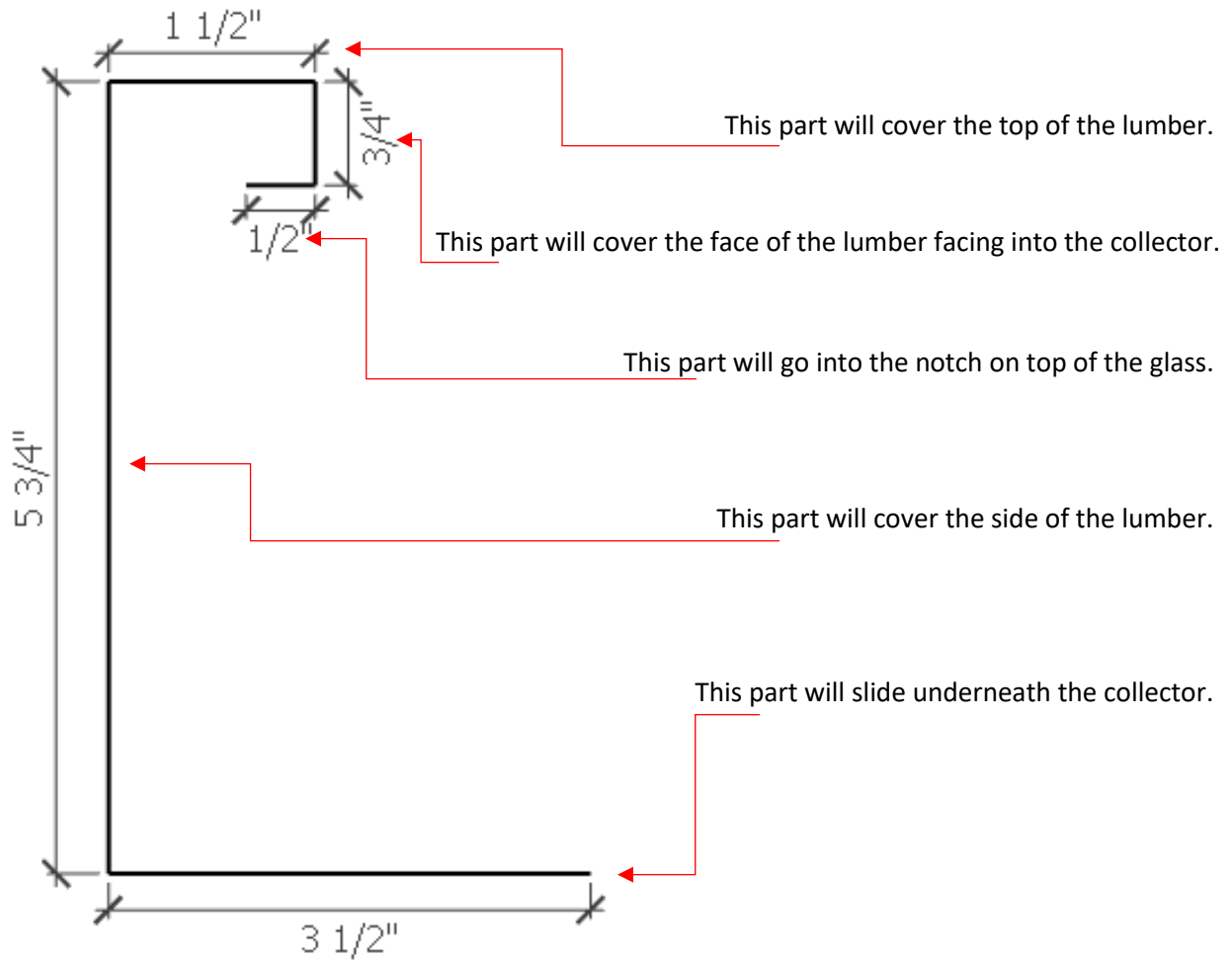


Figure 46: Flashing Profile for the Top and Side Edges of the Collector

PART 1: Solar Thermal Collector Fabrication Plan

For the bottom of the collector frame, measure out the following bends on the remaining 4'3" piece of flashing:

- From the edge of the collector measure and mark off 1½".
 - This will go underneath the glass and cover the top part of the wood on the collector.
 - Insert the flashing into the bender, with 1½" piece sticking out of the front of the bender. Ensure the measurement of the flashing is straight on the bender. Raise the arm of the bender to create a 90° bend on the flashing.
- From the previous bend measure out 4¾" and add 1/16" to the measurement¹² (i.e., total of 4-13/16").
 - This will cover the side of the collector.
 - Insert the flashing into the bender, with the previous bend sticking out of the front of the bender. Ensure the measurement of the flashing is straight on the bender. Raise the arm of the bender to create a 90° bend on the flashing.

Note: When measuring the location of the bends, double check the measurements on the collector's frame to validate the given measurements. When measuring the collector's framing, do not forget to account for the thickness of the OSB panel attached to the back of the collector frame.

The resulting profile for these bends is shown in Figure 47.

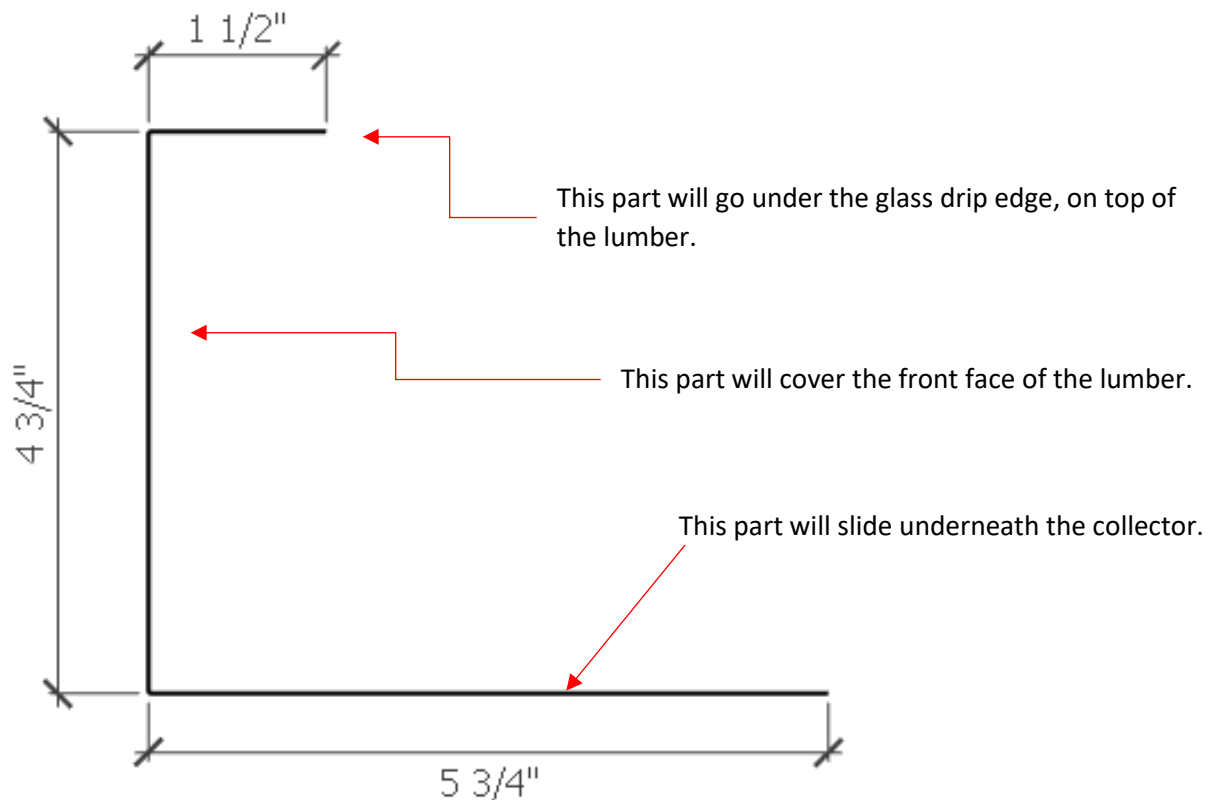


Figure 47: Flashing Profile for the Bottom Edge of the Collector

Flashing for the Bottom Part of the Collector

The first piece of flashing that will be attached to the collector will be the bottom piece that is made to fit on the bottom side with the glass jutting out of the frame. Before sliding in the flashing, notch out 2½" on either side of the flashing on the 1½" flat piece using snips as shown in Figure 48. This allows the flashing to slide underneath the glass while still allowing overhang on the sides of the collector. Follow these steps closely and in order as written to ensure overlaps prevent water penetration into the collector frame.

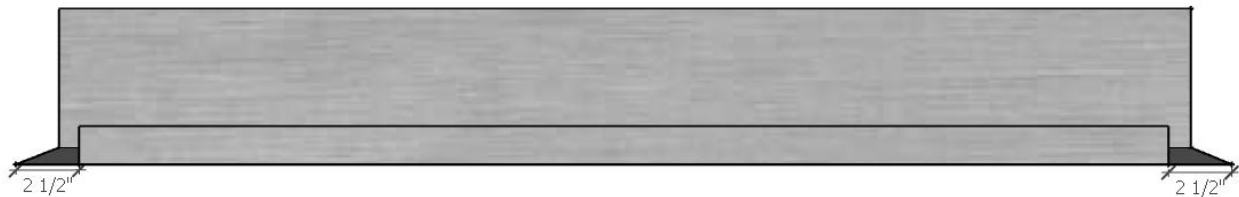


Figure 48: Notching the Bottom Flashing to Allow Insertion Under the Glass Panel

Using snips, cut approximately 1½" along the bend of the flashing on either side of the overhang or until the cuts line up with the edge of the collector as shown in Figure 49. There will now be two tabs on either side of the flashing.

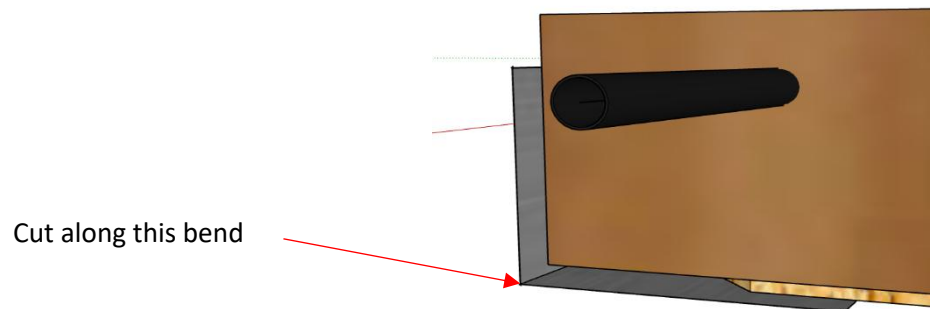


Figure 49: Cutting the Flashing Along the Bend to Create Tabs

Fold the tab on the bottom of the collector up using your hands as shown in Figure 50. Ensure the bend is tight to the collector, use a rubber mallet to flatten the flashing against the frame of the collector by tapping it lightly (the hand bender may also help with this).

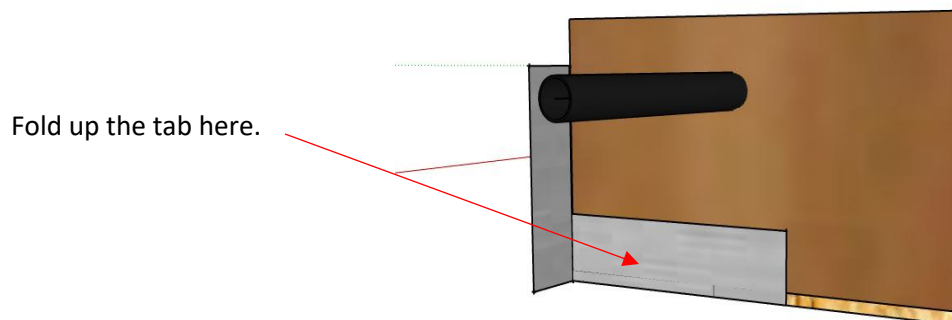


Figure 50: Folding the Bottom Tab Up onto the Collector Frame

Next, fold the tab on the side up against the side of the collector and on top of the bottom tab as shown in Figure 51. Make sure the flashing is tight against the collector by using a rubber mallet to tap it against the frame.

Fold the side tab in,
and over the bottom
tab.

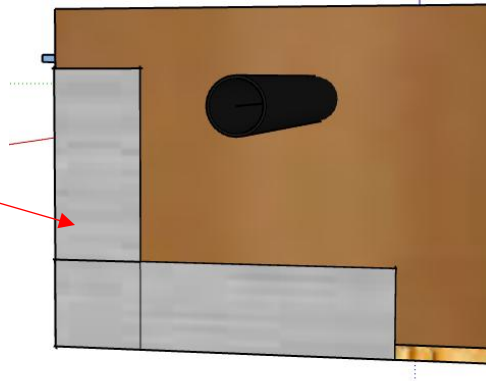


Figure 51: Folding the Side Tab onto the Collector Frame

Repeat this process on the other side of the flashing.

Flashing for the Sides of the Collector

Take one of the side pieces and position it beside the left side of the collector frame. At the end of the flashing next to the top of the collector, notch out 3" on the $\frac{1}{2}$ " and $\frac{3}{4}$ " flat pieces as shown in Figure 52. This will allow the flashing to slide into the collector frame and clip over the glass panel.

Trim the flashing
at the top corner
of the collector.

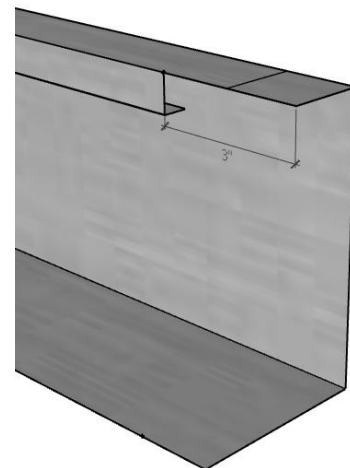
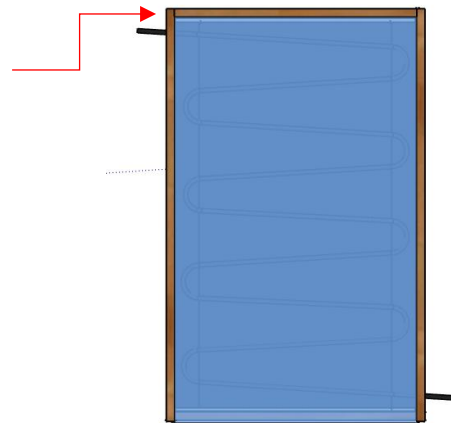


Figure 52: Notching the Top of the Side Flashing

Using the notch as a reference, line the flashing up with the collector frame and note the position where the absorber pipe will pass through the flashing by marking off the centre of the pipe from the side and bottom. Drill a 1" (D) hole for the pipe to go through at the marked location.

PART 1: Solar Thermal Collector Fabrication Plan

On the other end of the flashing where it lines up with the bottom of the collector, notch out a $1\frac{1}{2}$ " piece on the $\frac{1}{2}$ " flat section as shown in Figure 53. Carefully slide the side flashing over the collector frame and into the notch in the wood on top of the glass. This may take a few tries. The hand bender can be used as a straight edge guide to help manipulate the aluminum edge into the notch between the glass and frame edge.

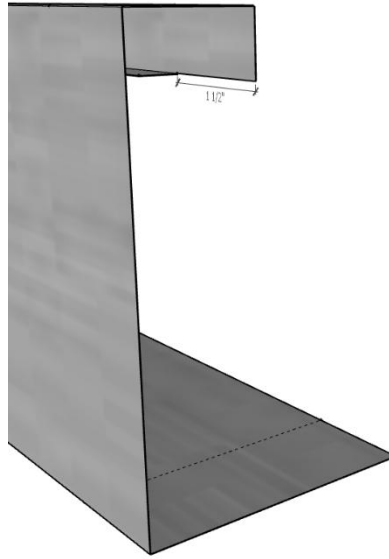


Figure 53: Notching the Bottom of the Side Flashing

Once the side flashing is on the collector there will be approximately a $1\frac{1}{2}$ " overhang on either end as shown in Figure 54. Using snips, cut along the two bends in the flashing up to the wooden collector frame and separate the flashing into three separate tabs.

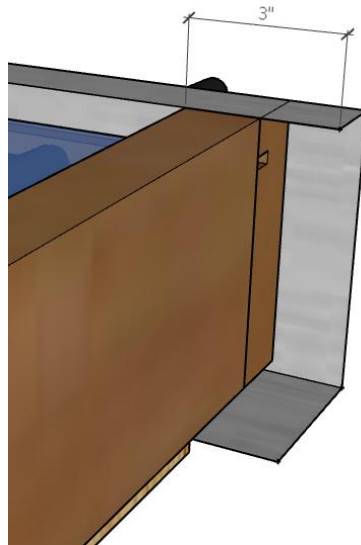


Figure 54: Side-Flashing Overhang at the Ends of the Collector Frame

PART 1: Solar Thermal Collector Fabrication Plan

At the top end of the side flashing, first fold the bottom tab up and flush to the collector frame as shown in Figure 55.

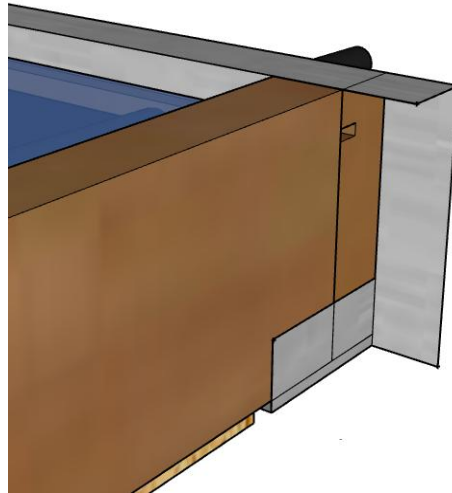


Figure 55: Folding the Bottom Tab of the Side Flashing at the Top End of the Collector

Next, fold the side tab into the collector and ensure it is flat up against the frame, using a mallet to flatten it further against the collector frame as shown in Figure 56.

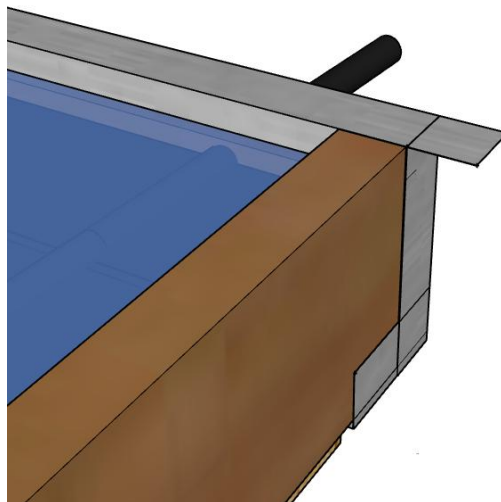


Figure 56: Folding the Side Tab of the Side Flashing at the Top End of the Collector

PART 1: Solar Thermal Collector Fabrication Plan

Finally, fold the top tab down over the collector as shown in Figure 57. This tab should overlap the side tab. Make sure the flashing is flat against the collector.

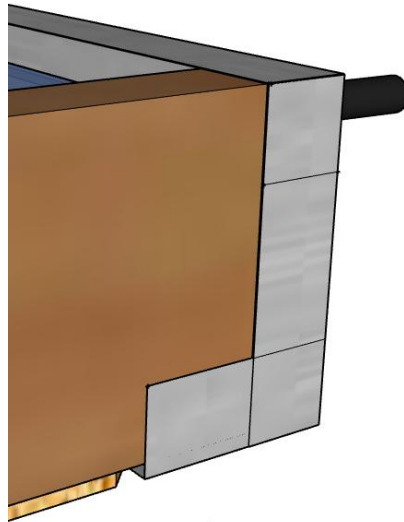


Figure 57: Folding the Top Tab of the Side Flashing at the Top of the Collector

At the bottom end of the side flashing, using snips, cut along the top two bends in the flashing up to the collector frame as shown in Figure 58, and separate the flashing into two separate tabs.

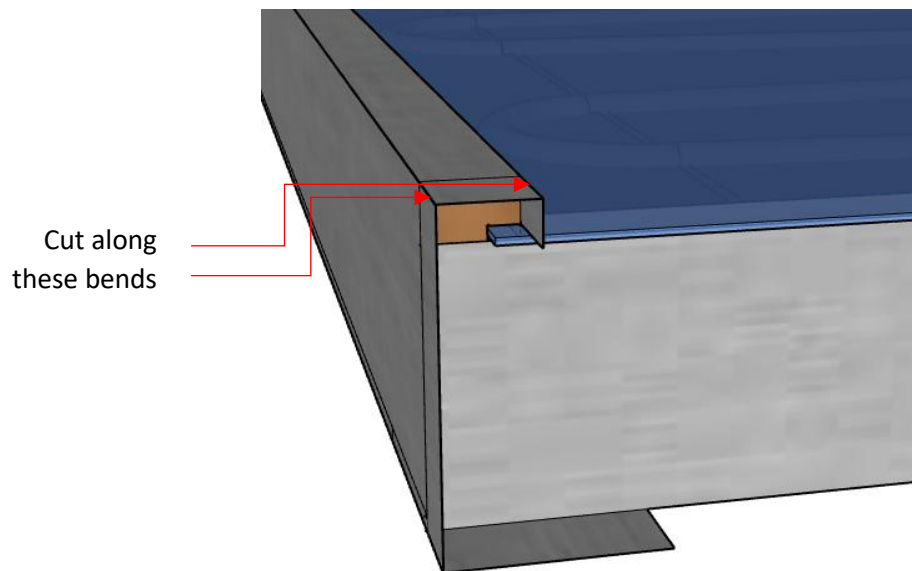


Figure 58: Cutting the Flashing Overhang Along the Bends to Create Tabs

First, fold the $\frac{3}{4}$ " inside tab over the edge of the collector frame as show in Figure 59.

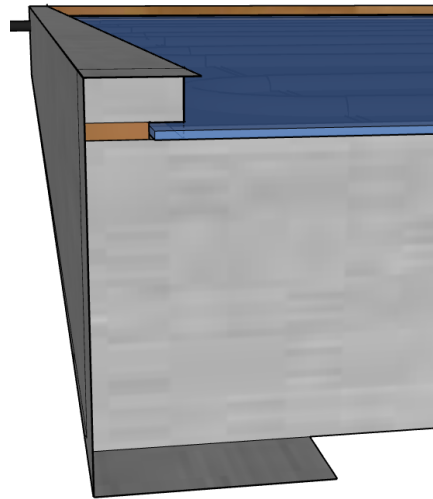


Figure 59: Folding the Inside Tab of the Side Flashing at the Bottom End of the Collector

Next, fold the $1\frac{1}{2}$ " top tab, trimming or notching it to accommodate the glass, as shown in Figure 60. Once the flashing piece has been trimmed, fold the top piece down on top of the other pieces of flashing.

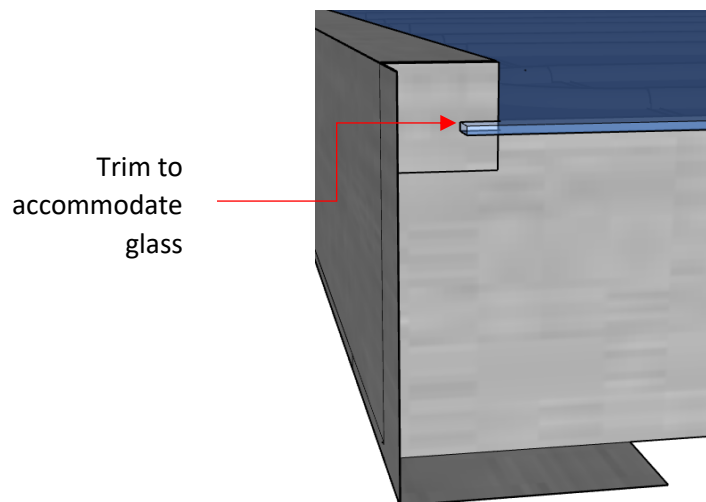


Figure 60: Notching and Folding the Top Tab of the Side Flashing at the Bottom of the Collector

Leave the bottom and side tabs of the flashing uncut and unfolded to act as a drip edge and allow for water to run off the collector. Depending how the collector is handled, you may later decide to cut away or fold in these drip edges (to make transport of the collector easier)

Repeat the same process for the other side flashing used on the right side of the collector. Make sure the notches and hole placements are on the correct end of the flashing by first lining it up with the side of the collector frame before cutting or drilling.

Flashing for the Top Part of the Collector

Take the remaining piece of flashing (4'-3" piece) and notch 3" off of either side of the flashing on the $\frac{1}{2}$ " and $\frac{3}{4}$ " flat sections as shown in Figure 61.



Figure 61: Notching the Ends of the Top Flashing

The notches will ensure that the flashing will fit the top part of the collector. Fit the flashing on the collector frame by inserting the $\frac{1}{2}$ " section of flashing into the groove in the wood on top of the glass. Again, this may take a few tries to manipulate the aluminum edge into the notch between the glass and frame edge.

Using snips, cut along the two bends of the flashing up to the collector frame at the top and bottom, creating three separate tabs as shown in Figure 62.

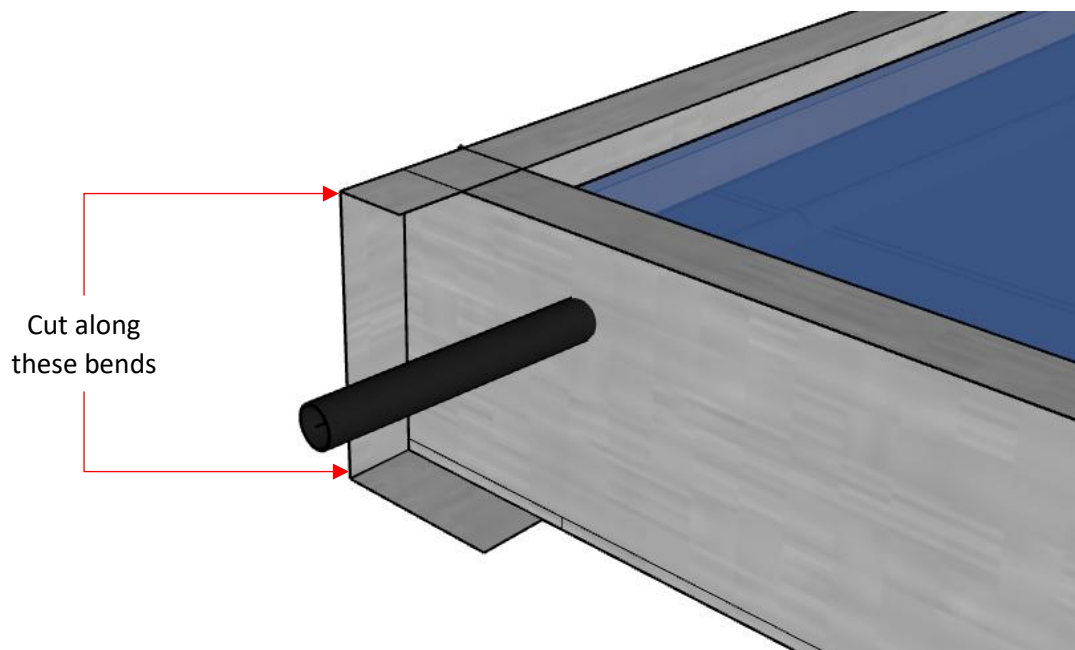


Figure 62: Cutting the Top Flashing Overhang Along the Bends to Create Tabs

PART 1: Solar Thermal Collector Fabrication Plan

First, fold the bottom tab up against the collector as shown in Figure 63.

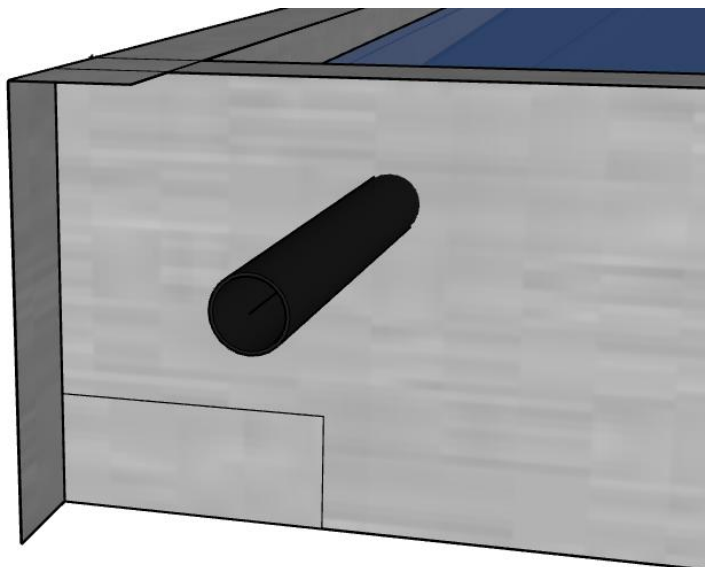


Figure 63: Folding the Bottom Tab of the Top Flashing Piece Against the Collector

Second, fold the side tab in against the collector as shown in Figure 64.

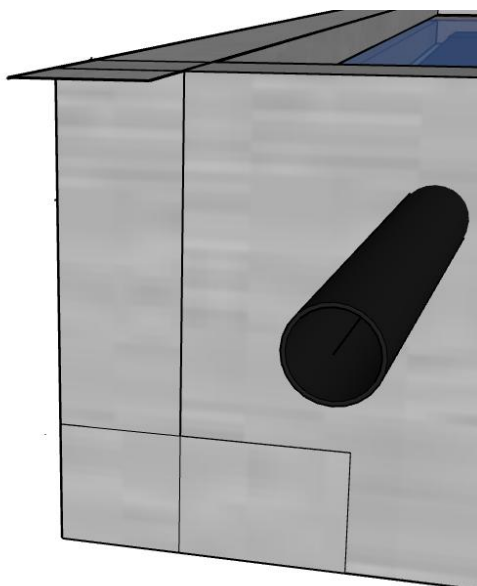


Figure 64: Folding the Side Tab of the Top Flashing Piece Against the Collector

Finally, fold the top tab down against the collector as shown in Figure 65.

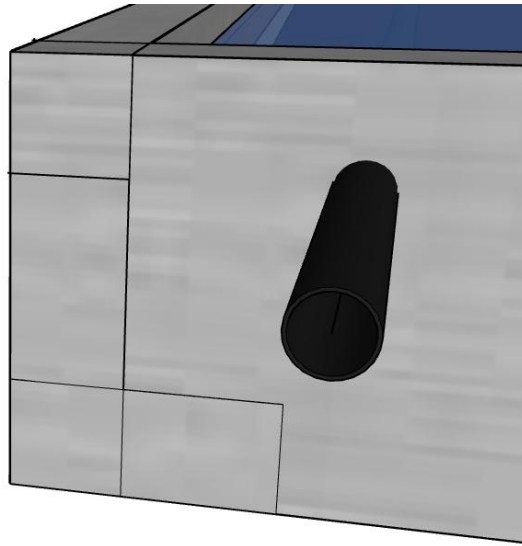


Figure 65: Folding the Top Tab of the Top Flashing Against the Collector

Run a bead of clear silicone along the back of the top piece of flashing. Press down on the piece and allow the silicone to seep out of the sides.

Repeat this process on the other side of the top piece of flashing.

Sealing the Glass and Securing the Flashing

Using the clear silicone caulking run a bead of the caulking where the flashing and glass meet on the face of the glass on three sides of the collector. Wearing nitrile gloves, you may use a finger to push caulking into the edge and form a smooth surface between the glass and aluminum. The goal is to ensure there are no gaps where water could seep into the collector.

Run caulking where there are seams in the flashing, and any gaps within the folds of the flashing.

Take the stainless-steel screws and thread nylon washers into the screws (or use aluminum nails). Drill screws (or hammer in nails) into the folded pieces of flashing, but do not secure the tabs at the bottom frame of the collector yet. Make sure the nylon washers are between the screw heads and the flashing. Aluminum nails can be used in place of costly stainless-steel screws (pilot holes may be needed as aluminum screws bend easily). **Note:** Due to dissimilar metals and corrosion, aluminum or stainless-steel should be used as fastener materials.

Sheet Metal Back Panel

Measure and mark off 19½" from the short edge of the 4' x 8' aluminum sheet. Bring the sheet over to the bending brake. Snips may also be used to cut the metal sheet.

Due to the throat depth of the bending brake only being 14", this cut will need to be done in 2 parts. .

For the first cut, insert the sheet metal into the bending brake the furthest it can go (i.e., 14"). Trim the sheet metal by clamping the bending brake down onto the sheet and using the utility knife, score the

PART 1: Solar Thermal Collector Fabrication Plan

sheet metal. After passing the knife along the sheet metal a few times, lift the arm of the bending brake up and move the sheet metal up and down until the cut has been made.

For the second cut, line up the bending brake with the marked off measurements on the aluminum sheet and trim the sheet with the utility knife as before. Set aside the leftover pieces of aluminum for use later.

The final aluminum back-panel measurements will be 4' 0" x 6' 4½".

To attach the metal back panel, the whole solar collector will need to get flipped over. This step will need a few people, as the collector will need to get lifted. When picking up the collector, ensure that the collector is picked up by the frame and not the piping, and that the glass does not shift in the frame.

Line up the sheet metal back panel so that it is centered on the back of the collector.

On each corner of the sheet metal, measure 2" from the top or bottom, and 2" from the side as shown in Figure 66. Drill a 3/8" (D) hole through the sheet metal back panel and unfastened flashing. These will create drainage holes.

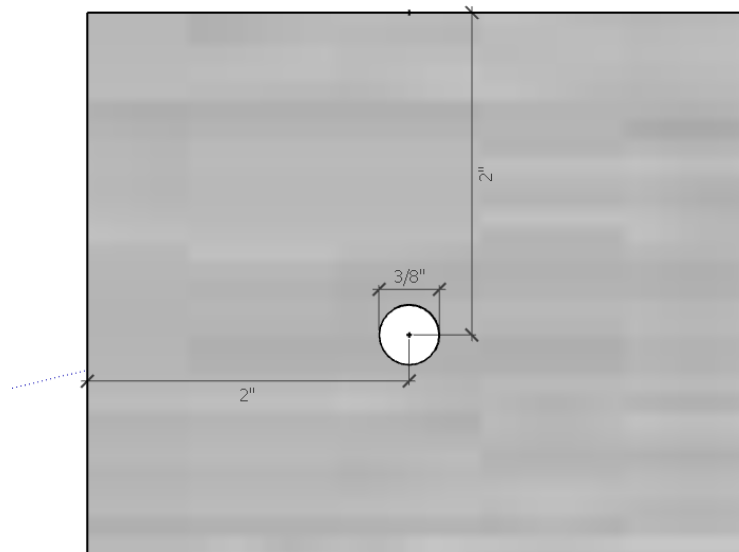


Figure 66: Drilling 3/8" Drainage Holes in the Corners of the Back Panel

Cut a minimum 2" x 2" piece of screen and slide it under the aluminum back panel to cover the hole. Secure the back panel to the collector frame using aluminum trim nails.

Note: It is important to use aluminum nails to prevent corrosion of the aluminum casing; Do not substitute galvanized steel or other metal nails.

Run silicone caulking under the perimeter of the back panel before nailing it down to seal it and to prevent water from seeping into the collector.

If the aluminum nails bend during nailing, drill a small pilot hole through the sheet metal before inserting the nails at regular intervals (approximately 6") around the perimeter. Take care to ensure that the nails are going into the wooden frame and not the insulation.

PART 1: Solar Thermal Collector Fabrication Plan

Flashing to Protect the Glass Edge

Using a piece of aluminum sheet leftover from the back panel, trim a piece of aluminum that is 3" wide and 4' 0" long.

Note: You may wish to cut this flashing piece into two 6" wide sections and attach only at the corners of the collector. Using the full length of aluminum is difficult to seal properly against the bottom edge of the glass. You will learn after the first build your own preferred approach.

Measure 1½" from the edge of the flashing and bend it 90° as shown in Figure 67.

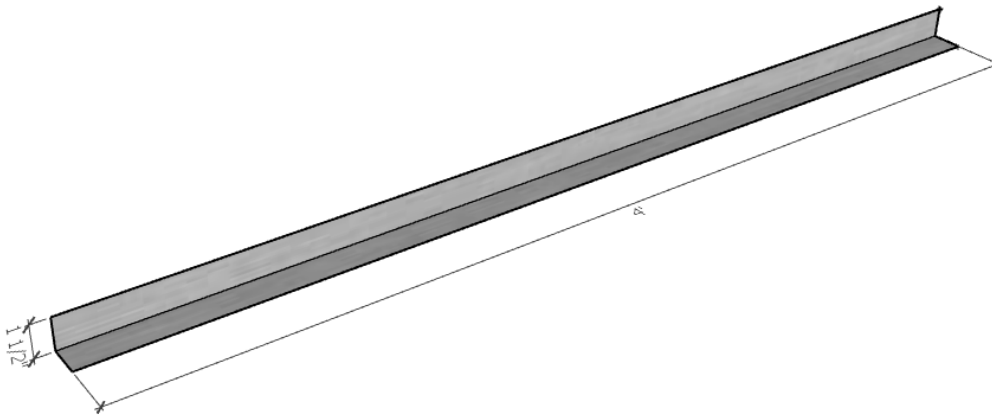


Figure 67: The First Bend in the Glass-Edge Flashing

Place the flashing piece up against the bottom of the collector frame and mark off where the glass-edge lines up with the flashing as shown in Figure 68 (it may not be square and that is ok).

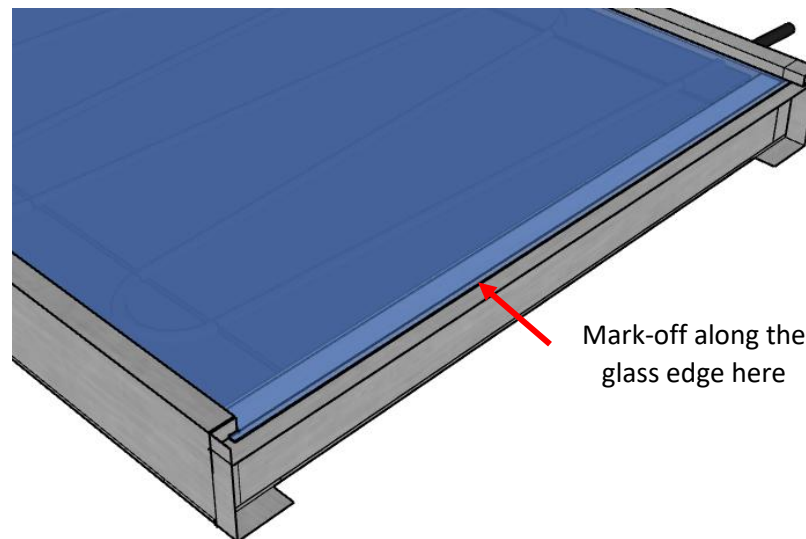


Figure 68: Marking the Location of the Second Bend on the Glass-Edge Flashing

PART 1: Solar Thermal Collector Fabrication Plan

Bend the flashing up 90° along mark. The resulting flashing shape will look like the one shown in Figure 69.

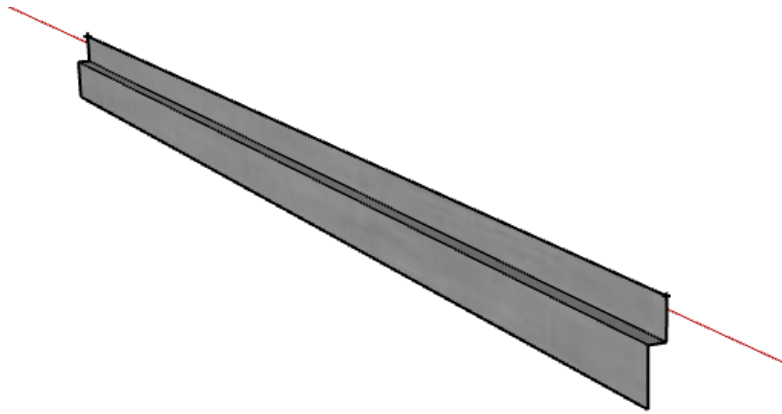


Figure 69: The Second Bend in the Glass-Edge Flashing

Put the flashing piece up against the collector frame a second time and mark off where the top edge of the glass meets the flashing (again, it may not be square and that is ok).

Start this final bend using the bending brake, however you will not be able to make the full 90° bend due to the previous profile bent in the flashing. Use a hand bender to complete the bend by gradually working along the length of the flashing so that it wraps around the glass. Bend and squeeze the flashing so that it fits as tight as possible to the top surface of the glass.

The final bend profile is shown in Figure 70.

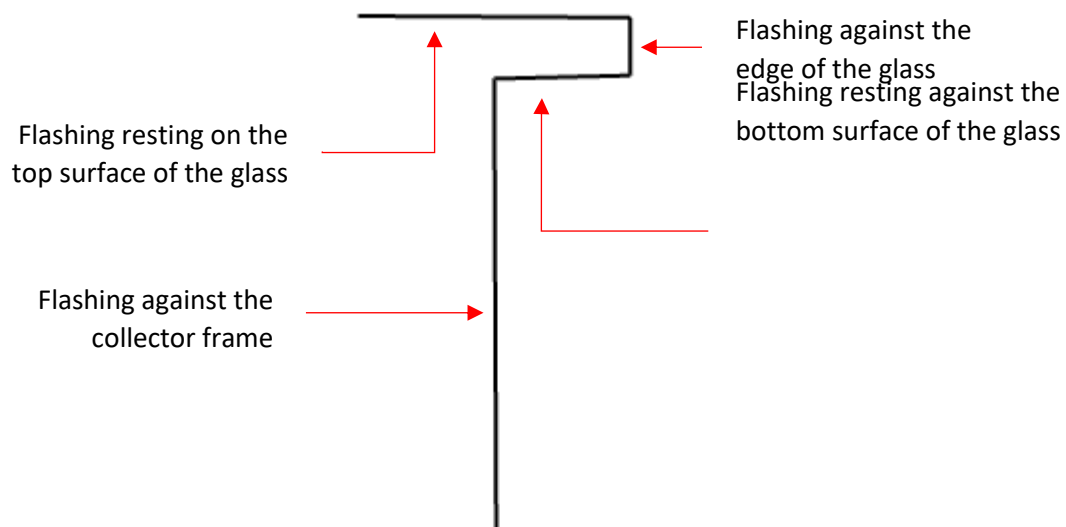


Figure 70: The Final Bend Profile for the Glass-Edge Flashing

PART 1: Solar Thermal Collector Fabrication Plan

Make cuts into the top edge of the glass-edge flashing on both ends that line up with the side edges of the glass panel as shown in Figure 71.



Figure 71: Trimming the Glass-Edge Flashing at the edges of the Glass Panel to Create Tabs

Extend these cuts along all the bends made on the flashing, and trim from the sides to create a tab on each end of the flashing that rests on the surface of the collector frame.

Tuck this tab behind the top tab that was formed by the side pieces of flashing. Run a bead of silicone caulking behind the piece of flashing and press down on it to seal the seams.

Drill and install a stainless-steel screw fitted with a nylon washer through the tab to fasten the ends of the flashing to the frame (or use aluminum nails). Do this for both sides.

Complete attaching the glass-edge flashing by drilling and installing stainless-steel screws fitted with nylon washers along the flashing at regular intervals, approximately 8" apart (or use aluminum nails).

Finally, run a bead of silicone caulking where the flashing meets the glass, sealing any gaps.

PART 2: Solar Hot Water System Installation

Collector Location and Orientation

The following information has been extracted from NRCan's Solar Ready Guidelines [Ref 1], and adapted to focus on solar domestic hot water (SDHW) systems installations. Users are encouraged to download this reference document for additional information.

Collector Location and Shading Considerations

In most residential applications, roof-mounted equipment is the most cost-effective way to install solar energy systems. The roof space specifications for a rooftop installation of two 1.2 m (4') x 1.8 m (6') flat-plate solar thermal collectors, allowing 30 cm (12") of work space above and below the collectors as well as 6" between each collector, is shown in Figure 72.

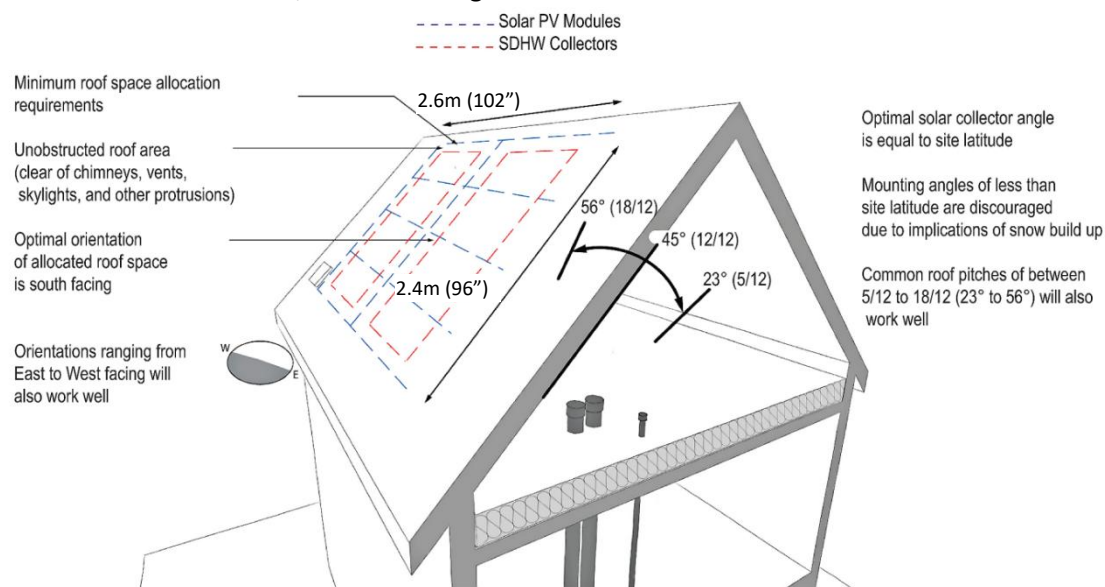


Figure 72: Roof Space, Orientation and Mounting Angle Considerations [Ref 1]

A site inspection of surrounding building structures and trees will ensure the allocated area will not be significantly shaded by surrounding buildings and / or mature trees at any time of the year.

Solar shading considerations are described in Figure 73.

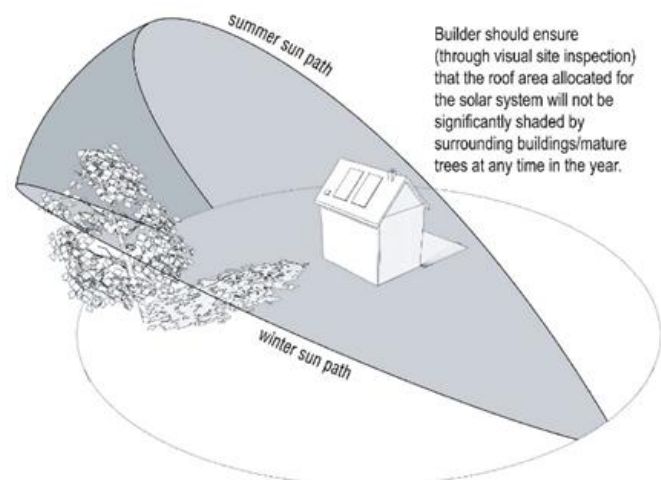


Figure 73: Shading Considerations for Solar Systems [Ref 1]

Collector Mounting Angle

From the standpoint of maximizing the annual solar energy collected, the ideal collector mounting angle is generally equal to site latitude. Users can consult the Solar Resource Maps of Canada [Ref 2] for additional information. Vertical mounting of solar collectors is also possible, but should generally be limited to extreme northerly locations (see seasonal optimisation below).

It should also be noted that systems mounted at low angles (generally 45° (12/12) pitch or less) will not shed snow as well as systems mounted at slightly steeper angles and will thus not perform as well in winter months.

For optimum solar performance, the recommended roof pitch is 5/12 to 18/12, corresponding to angles of between 23° and 56° above horizontal (0°). Roof mounting kits are available for low slope or flat roofs to achieve the desired mounting angle. Installers and homeowners should be aware of load implications associated with using such kits if chosen.

Collector Orientation

From the standpoint of maximizing solar energy collected, the ideal collector orientation is south facing. However, based on a design target of not less than 70% of maximum performance, and taking into consideration that some lots will not allow for optimal orientation, recommended roof space orientations varying between east and west facing.

Seasonal Optimisation

Solar systems can be designed to perform best in summer or winter, depending on the intended use and site location. As most SDHW installations tend to “over-perform” in summer and “under-perform” in winter. Installers and homeowners, particularly in extreme northerly locations, may wish to design for improved winter performance by allocating a steeper sloping area of roof space (or wall space) and/or allocating roof space with a modified orientation.

As a general rule of thumb, SDHW systems are optimized for winter performance, and will perform best at mounting angles 10 degrees greater than site latitude and oriented slightly west of due south. The effects become more pronounced the further north the site is located.

PART 2: Solar Hot Water System Installation

Collector Mounting

Two collectors will be mounted on a south-facing roof slope or on a south-facing wall of the house using L (angle) -brackets for attachment to the structure. A mounting area about 102" wide and 96" length (height) will be required. **The collectors must be mounted in the portrait position.** Collectors can be mounted in parallel, in which flow is split equally between the collectors (using headers) or in series, in (in which the outlet of one collector flows into the inlet of the other collector). Mounting parallel with split flow is preferred from an efficiency perspective but is more difficult to install. Mounting in series may be less efficient but requires significantly less installation time and offers the flexibility of installing collectors beside one another, above one another or offset. As parallel installation requires more steps, it will be covered here. For low slope roof surfaces, mounting the collectors using struts so that they can be appropriately tilted may be necessary.

Materials needed for roof or wall mounting to non-masonry walls

- 2 assembled Solar Collectors
- 8' M-D Building Products 3/16" x 1-1/4" Camper and Truck Panel Foam Air Sealing Tape (or similar)
- 8 Simpson Strong-Tie Gauge 12, 5-7/8" x 5-7/8" x 1-1/2" Galvanized Steel Angles; (model A66 or similar)
- 16 1/4" or 5/16" x 3-1/2" GRK RSS Rugged Structural Screws, Star Drive
(**Note:** Different screw lengths may be needed depending on thickness of the exterior wall cladding; longer lengths may only be available in 5/16" screws)
- 16 1/4" x 1-1/2" GRK RSS Rugged Structural Screws, Star Drive (or similar)
- Approximately 16' of 2" x 4" SPF lumber (to be used as structural blocking, 2" x 6" or 4" x 4" will also work)
- 16 #9 x 3-1/8" R4 Multi-Purpose Framing Screws, Star Drive (or similar) for fastening structural blocking to top chords / rafters

Materials needed for wall mounting to masonry walls

- 2 assembled Solar Collectors
- 8' M-D Building Products 3/16" x 1-1/4" Camper and Truck Panel Foam Air Sealing Tape (or similar)
- 8 Simpson Strong-Tie Gauge 12, 5-7/8" x 5-7/8" x 1-1/2" Galvanized Steel Angles; (model A66) (or similar)
- 16 Buildex Tapcon Concrete Anchors, 1/4" x 2-1/4", Slotted Hex Drive Screws (or similar)
- 16 Paulin 1/4" x 1-1/2" GRK RSS Rugged Structural Screws, Star Drive (or similar)

Tools needed for roof or wall mounting to non-masonry walls

- Mitre saw
- Drill
- 3/16" Drill bit
- T-25 and T-30 Star drive
- Tape Measure
- Chalk line
- 48" Level or line level
- Metal Snips

PART 2: Solar Hot Water System Installation

- Wooden blocking, 3/4" thick
- Stud finder

Additional Tools needed for mounting to masonry walls

- Electric Hammer Drill
- 3/16" x 7" Carbide Tipped Concrete Drill Bit (sized for 1/4" Tapcon Concrete anchor screws)
- 1/4" Socket drive

Various Mounting Methods for Asphalt-Shingled Roofs

The most common solar attachment methods for residential projects involve anchoring collectors to the roof substructure (e.g., roof trusses).

Four techniques for doing this, in order of most preferred to least preferred, are:

- i. Using J-bolts or U-bolts that hook under or around truss top chords.
- ii. Using structural blocking secured between trusses using approved fasteners. This allows lag bolting into the blocking without fear of truss damage. This requires access to the attic and is the most common approach used.
- iii. Lag bolting into scab members that have been attached to the side of roof-truss top chords following the procedures described in Truss Plate Institute of Canada, technical bulletin #7 [Ref 3].
- iv. Direct lag bolting of anchors into roof-truss top chords is also commonly used by solar installers*.

*** NOTE to Installers from the Truss Plate Institute of Canada (TPIC) [Ref 3]**

TPIC Solar Ready (SR) trusses are not designed to accommodate lagging directly into truss top chords. This method of attachment is not recommended by the TPIC.

Identify the area on the roof surface where the collectors will be mounted, and locate and mark the positions of the roof-truss top chords on the roof surface¹³. The area required for two collectors will be about 102" width and about 96" height¹⁴. It is ideal to have one person on the roof and one person in the attic to enable communication of the appropriate location for the collectors.

¹³ A number of methods are available to identify truss top chords. If the top chord "tail" can be identified from within the roof eaves, this can be done from above and can provide one point of measurement (by removing soffit covers). Radar based detecting scanners may be used. However, the most reliable approach is to get access to the attic space in the home and identify the roof truss top chord members. If attic access is possible, drill a pilot hole from below, adjacent to the top chord and make note of the distance between top chords (e.g., 16" on centre).

¹⁴ The width of the collectors is 48" each and about 6" of work space should be left between each collector. The total width of the required area for the two collectors is therefore about 48" + 6" + 48" = 102". The length of the collectors is 72" each and about 12" of work space should be left above and below each collector for the collector header plumbing. The total length of the required area for the two collectors is therefore about 72" + 12" + 12" = 96".

PART 2: Solar Hot Water System Installation

Roof Mounting using Structural Blocking between Truss Top Chords

From on the roof, measure and locate the preferred location of the bottom edge of the collector, and mark a horizontal line on the roof using a level and chalk line.

From within the attic, measure the distance between truss top chords / roof rafters and, using the mitre saw, cut the 2" x 4" x 8' lengths of structural blocking into the required lengths.

Rest the two collectors on the roof above the bottom angle brackets. Lift and insert temporary wooden blocking at the bottom and top of the collectors to create approximately a $\frac{3}{4}$ " gap between the roof deck and the collector, and adjust the collector positions to leave enough space between the two collectors to make the plumbing connections to the headers (if installing in parallel) and for installing piping insulation.

Position two angle brackets per bottom edge of the collector along the chalk line, equally spaced along the collector edge and drill one pilot hole for one of the angle brackets from above the roof into the attic below (communicate with the person in the attic to ensure this pilot hole will not penetrate a truss top chord / roof rafter before drilling). This serves as a marker of the desired location of the collector. Measure the distance between this pilot hole and where the next hole would be for the second desired angle bracket placement along the bottom edge of the collector. The person in the attic can use the drilled pilot hole to position the blocking between the truss top chord / roof rafters for mounting the structural blocking and can use the measurement to the other angle bracket to ensure it will not penetrate a top chord / roof rafter. The structural blocking for the first angle bracket can now be attached to the truss top chords / roof rafters. To do this, hold the length of structural blocking against the roof deck (ensuring the pilot hole will land centred in the structural blocking width), and drill through the side of the top chord / roof rafter into the ends of the structural blocking¹⁵ using four of the #9 x 3 1/8" GRK R4 Multi-Purpose Framing Screws (two per blocking edge).

Before attaching the angle brackets to the roof, check the dimension of the angle brackets against the bottom of collector. The one leg of the bottom angle brackets may need to be trimmed shorter to prevent interference with the glass drip-edge protruding from the bottom of the collector. Remember to include the roof-to-collector gap dimension ($\frac{3}{4}$ ") when checking for interference.

Measure a length of panel foam (approximately 6" long) that is long enough to cover the entire length of the galvanized angle bracket that would touch the collector. Stick the foam onto each of the bottom brackets to prevent direct contact with the aluminum flashing on the collectors. Attach the first angle bracket to the bottom edge of the collector at the desired location along the collector edge using two $\frac{1}{4}$ " x 1-1/2" GRK RSS Rugged Structural Screws.

With the second angle bracket in the desired position along the bottom edge of the collector, drill the second pilot hole from above through the roof surface to the attic below. The person in the attic can use this pilot hole to position the second blocking length and attach the blocking to the truss top chord / roof rafter as previously described.

The two angle brackets can be attached to the bottom edge of the solar collector using the $\frac{1}{4}$ " x 1-1/2" GRK Round Washer Head RSS Rugged Structural Screws (two per angle bracket into the bottom edge of

¹⁵ Angle brackets can also be used to fasten the structural blocking to the truss top chord / roof rafter edges.

PART 2: Solar Hot Water System Installation

the collector). The angle brackets can also be fastened into the structural blocking that has been mounted under the roof surface using the ¼" or 5/16" x 4" GRK Round Washer Head RSS Rugged Structural Screws (two per angle bracket into the structural blocking mounted below the roof deck).

Moving to the top of the collectors, install two angle brackets with panel foam using the same spacing and attachment method as was used with the bottom brackets.

Repeat the process for the second collector.

Remove the temporary blocking between the collectors and roof deck.

Wall Mounting

The attachment method of collectors to the house wall will depend on the material used for exterior cladding at the collector mounting location.

- a. If the exterior wall is wood, vinyl, aluminum siding or brick veneer (i.e., non-masonry walls) attachment of angle brackets will be made to the wall studs using GRK RSS Rugged Structural Screws. Screw length should be selected based on the thickness of the exterior wall cladding system to allow approximately 2-1/2" to 3" of thread penetration into the wall stud.
- b. If the exterior wall is concrete block or poured cement, attachment of angle brackets will be made to the masonry wall with concrete anchors such as Tapcon Concrete Anchor Screws, ¼" x 2-1/4".

On a suitable south facing wall or gable, identify and mark the wall location of where the collectors will be mounted. Locate where the bottom edge of the collector will be, which must be above the maximum snow level, and mark a horizontal line on the wall using a level and chalk line.

- a. For non-masonry walls, locate and mark the position of the wall studs along the chalk line. A stud finder may assist with this task.

Position two angle brackets per collector along the chalk line and drill two pilot holes per bracket that match the hole placement of the galvanized angles.

- a. For non-masonry walls, drill pilot holes through the wall cladding into the center of the wall studs.
- b. For masonry walls, drill into the wall using a carbide-tipped drill bit sized for the Tapcon Concrete Anchors, and deep enough to accept the screw length into the wall as per manufacturers specifications.

Before installing the bottom angle brackets on the wall, check the dimension of the angle brackets against the bottom of collector. The one leg of the bottom angle brackets may need to be trimmed shorter to prevent interference with the glass drip-edge protruding from the bottom of the collector. Remember to include the wall-to-collector gap dimension when checking for interference.

Measure a length of panel foam (approximately 6" long) that is long enough to cover the entire length of the galvanized angle bracket that would touch the collector. Stick the foam onto each of the bottom brackets to prevent direct contact with the aluminum flashing on the collectors.

PART 2: Solar Hot Water System Installation

- a. For non-masonry walls, attach the four bottom angle brackets onto the wall using two ¼" GRK Structural Screws of a suitable length through each angle bracket into the wall studs.
- b. For masonry walls, attach the four bottom angle brackets onto the wall using two Tapcon, ¼" x 2-1/4", Concrete Anchor Screws through each angle bracket into the previous drilled pilot holes.

Rest and support the two collectors against the wall on the bottom angle brackets. Insert temporary wooden blocking at the bottom and top of the collectors to create approximately a ¾" gap between the wall and the collector, and adjust the collector positions to leave enough space between the two collectors to make the plumbing connections to the headers and for installing piping insulation.

Once the collectors are properly positioned, secure each bottom bracket to the collector by installing two ¼" x 1-1/2" GRK RSS Rugged Structural Screws through each angle bracket into the frame of the collector, taking care to not damage the glass drip-edge jutting out of the bottom of the collector.

Move to the top of the collectors, and install four angle brackets with panel foam using the same spacing and attachment method as used with the bottom brackets.

Remove the temporary blocking between the collectors and exterior wall.

PART 2: Solar Hot Water System Installation

Collector Headers and Distribution Piping

Two collectors will be plumbed together with top and bottom headers made of copper piping, which will be extended to connect to the storage tank using PEX piping. Piping will penetrate either the roof or the wall of the house through weatherproof flashings. All piping will be insulated.

Materials needed:

- 2 x Solar Collectors mounted on the roof or wall of the house
- 4 x copper bushing adapters from 3/4-in OD refrigeration to 3/4" ID plumbing
- 6 x copper 3/4" ID 90° elbows
- 4 x copper 3/4" ID tees
- 2 x copper 3/4" ID caps
- 2 x 1" PEX to 3/4" ID copper female sweat adapters
- 3/4" copper pipe (length required to be determined on site)
- 1" PEX fittings and crimp rings (number and type of fittings to be determined on site)
- 1" PEX piping (length required to be determined on site)
- 95% Tin Solder
- Soldering paste
- 2 pieces of 3" PVC piping (each approximately 18" long)
- 2 x Flex roof plumbing boot flashing for 3" PVC pipe (if using roof penetrations) and butyl tape to seal to the roof surface
- Roofing nails (if using roof penetrations)
- Silicone caulking (UV resistant)
- Steel strapping
- #8 x 1-1/2" wood screws for attaching strapping (number to be determined on site)
- Piping insulation with weather and UV protective covering (see description for options)
- Hot collector temperature sensor (see "Balance of System Section" for further details)
- Stainless-steel hose clamp (see "Balance of System Section" for further details)
- Rubber weather stripping (see "Balance of System Section" for further details)
- 2 conductor, 18 AWG sensor wire (see "Balance of System Section" for further details)

Tools needed:

- Tube cutter
- Soldering Prepping Tool
- PEX Pipe cutter
- Propane torch
- Emery cloth
- Acid brush
- Tape Measure
- 48" Level
- Hammer
- Metal Snips
- Stud Finder
- Drill with drill bits
- 3-1/2 Hole Saw
- Crimping tool for 1-in PEX

PART 2: Solar Hot Water System Installation

- Caulking gun

Fabricating the Collector Headers

The two serpentine collectors are joined together using top and bottom headers fabricated from $\frac{3}{4}$ " rigid copper piping and $\frac{3}{4}$ " copper sweat fittings as shown in Figure 74.

Each of the four, $\frac{3}{4}$ " OD refrigeration type ("soft") copper tubing stubs exiting the collectors is adapted to $\frac{3}{4}$ " ID plumbing type ("hard") copper piping using a copper bushing and a 90° elbow. Short pieces of copper piping are added, with lengths adjusted to ensure that the headers slope at a minimum of $\frac{1}{4}$ " per foot towards the tank, and that there is enough space between the header piping and collector frames for installing pipe insulation.

All four connections from the collectors to the header pipes are made using plumbing-tees to help balance the flow resistance and ensure equal water flow through each of the collectors.

Distribution Piping in Roof Installations

For roof installations, the header pipes are extended to two roof penetrations and plumbed into the attic through short lengths of 3" PVC drain pipe fitted with flex roof flashings that are inserted under the shingles as shown in Figure 75.

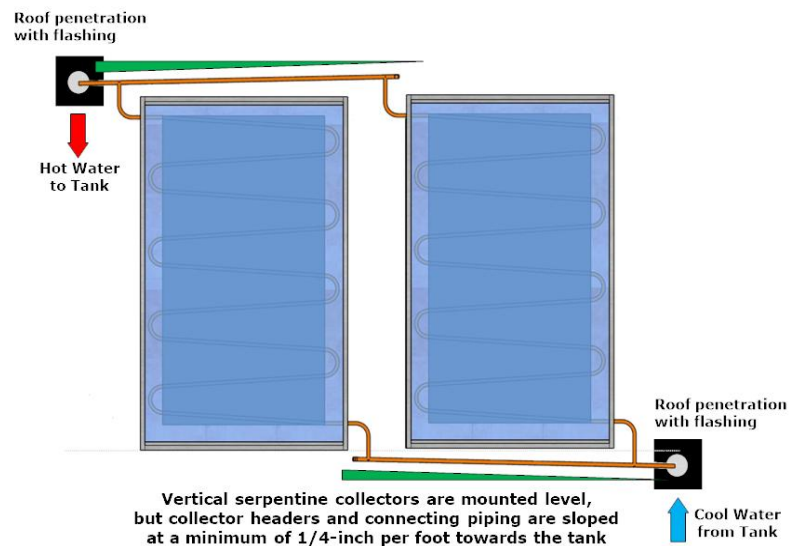


Figure 74: Two roof-mounted, serpentine collectors, connected by sloped headers fabricated from rigid copper plumbing.

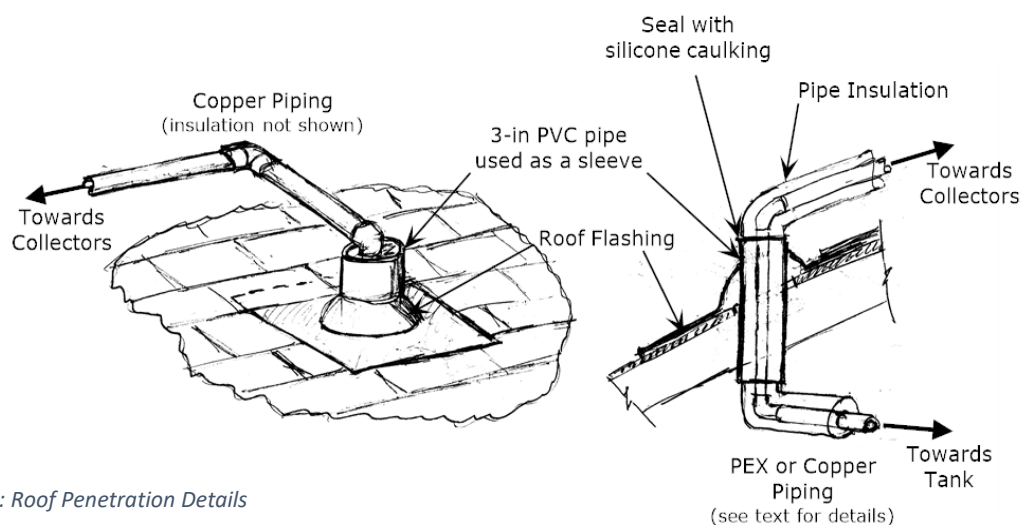


Figure 75: Roof Penetration Details

PART 2: Solar Hot Water System Installation

When locating roof penetrations, it is important to ensure all piping maintains the required slope towards the tank¹⁶. Once inside the attic, piping can be further extended to a ceiling location where vertical pipes can be routed to the storage tank, such as over the back of a closet or other suitable area that can be used as a plumbing chase. **It is critical to ensure all attic piping maintains the proper slope towards the tank¹⁶.**

Horizontal piping runs in the attic:

- If the attic piping can be suitably strapped (i.e., about every 3') to prevent sagging, these piping runs can be fabricated using 1" PEX piping. When fastening distribution piping to rafters / trusses to prevent sagging, wrap the pipe insulation with tape or jacketing and use nylon coated strapping to prevent the strapping from cutting into the pipe insulation.
- If strapping the piping at regular intervals is difficult, it is recommended that attic piping be fabricated using ¾" ID plumbing ("hard") copper piping.

Vertical piping from the attic:

- Vertical piping from the attic to the storage tank area can be fabricated using 1" PEX piping.

Distribution Piping in Wall Installations

For wall installations, the header pipes are adapted from ¾" ID plumbing ("hard") copper to 1" PEX piping and distribution piping is routed on the outside of the building to above a wall area near the storage tank. Piping enters through two wall penetrations into the house, basement, or crawl-space via 3" PVC pipe sleeves inserted and sealed to the wall with caulking. It is important to ensure all horizontal sections of piping maintain the proper slope towards the tank¹⁶.

Thermal Insulation of Collector Headers and Distribution Piping

Collector headers and all distribution pipes are to be insulated using pipe insulation. The insulation used on exterior piping needs to be weatherproof and ultraviolet resistant. Two possible options include:

1. Insulate piping with 1" wall thickness Armaflex or equivalent rubber type insulation rated for 230°F (110°C). Rubber pipe insulation exposed to the sun should be painted with a latex based insulation paint to resist UV degradation, or
2. Insulate piping with 1" wall thickness insulation of any type (e.g., fibreglass pipe insulation). In this case, exterior sections of piping should be covered using a UV-resistant (e.g., PVC) jacket, with all longitudinal seams and joints to elbow coverings sealed with an approved adhesive. Interior sections of pipe insulation can be taped.

Collector Temperature Sensor Installation

Before installing the pipe insulation on the outlet, or top collector header, the "hot collector temperature sensor" should be mounted on the collector outlet pipe as close as possible to edge of the collector, using a stainless-steel hose clamp. Put a strip of rubber weather sealant around the sensor and copper pipe and secure it with the stainless-steel clamp. Cover the sensor with pipe insulation.

¹⁶ All horizontal runs of piping from the collectors to the drainback tank should be sloped at a pitch of ¼" per foot minimum towards the tank, with piping laid out and secured to ensure no low points are created where water could become trapped. Very short sections (e.g., 6" run through a wall penetration) may be horizontal if sloped piping exists before and after the short section.

PART 2: Solar Hot Water System Installation

Distribution wiring from the temperature sensor to the system controller should be installed on the outside of the pipe insulation and under the PVC insulation jacket, if used. See the “Balance of System” Section for additional details.

Balance of System Installation

Components for “Balance of System” to complete the DX drainback solar hot water system, are to be purchased and installed following manufacturer’s instructions. The following provides general guidance on typical components and installation steps required, and is not intended to replace manufacturer’s instructions.

Materials needed

A DX drainback system consists of a collector array, a drainback reservoir that incorporates a heat exchanger, a storage tank, two pumps and a system controller.

The following material list is provided as an example.

- Storage tank (comes with a temperature / pressure relief (TPR) valve):
 - o A new electric solar storage tank (a tank with 4 ports), or
 - o An existing electric storage tank, with modifications (see section “Application Tips for Retrofit Installations using an Existing Electric Storage Tank” for details)
- 4 X ¾” copper unions (*to allow for easy change-out of storage tank*)
- Pump and controls: Two cartridge circulators with isolation valve flanges (one high head pump to circulate fluid to / from collectors and one low-head pump to circulate fluid between storage tank and drainback reservoir).
- Drainback reservoir tank with heat exchanger and sight glass
- Pressure Relief (PR) valve
- Drain valve
- Visual Thermometer and adapter bushings (*to aid commissioning and troubleshooting*)
- Isolation shut-off valves (*number to be determined on site*)
- Tempering valve (*if new installation*)
- PEX and/or copper piping and fittings (*length and type of fitting to be determined on site*)
- Teflon tape
- Solder and Solder Flux (*if using copper piping*)
- Emery cloth (*if using copper piping*)
- 2 conductor, 18 AWG thermostat wire (*to connect the temperature sensors to controller*)
- Wire nuts or connectors
- Stainless steel hose clamp
- Silicone sealant
- Steel coated pipe strapping and screws
- Cable ties (*UV resistant (black) ties for outdoor locations*)

Tools needed

- PEX pipe cutter (*if using PEX piping*)
- Crimping tool for 1” PEX
- Tube cutter (*if using copper piping*)
- Propane torch and striker (*if using copper piping*)
- Tape measure and level
- Pipe wrench
- Adjustable Wrenches (*e.g., 8”, 10”*)
- Slip-Joint Pliers

Natural Resources Canada

PART 2: Solar Hot Water System Installation

- Metal Snips
- Screwdrivers
- Wire cutters
- Wire stripper or knife
- Caulking gun

Balance of System Installation When Using a New Solar Storage Tank.

The installation of the balance-of-system components should be completed following the manufacturer's instructions.

When completed, the installation of the solar DX drainback hot water system will be similar to the one shown in Figure 76.

PART 2: Solar Hot Water System Installation

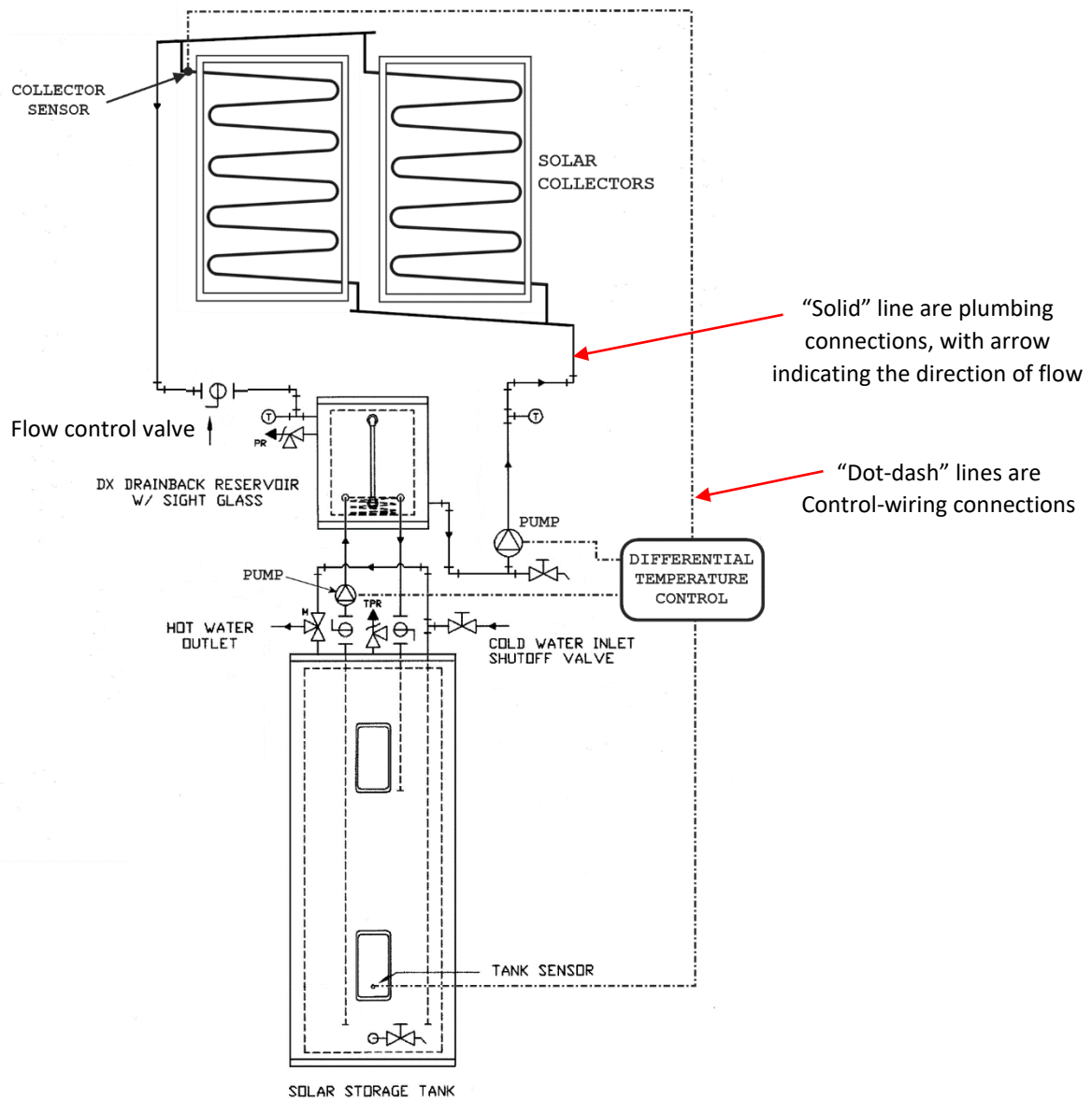


Figure 76: Schematic of a Solar DX Drainback System Using a New Electric Solar Storage Tank

Storage Tank Placement

Tank placement is important to ensure that there is minimal heat loss through the plumbing and in a proper location for the residence's domestic hot water system.

To minimize expense and heat loss, the tank should be placed near the collectors and central to points of greatest water demand. It should be located in as warm a spot as possible, away from areas which would subject the drainback reservoir to freezing temperatures. The storage tank should be installed on a stand above the floor to minimize heat loss and enable drainage through the tank drain port. It should

PART 2: Solar Hot Water System Installation

be located with adequate ventilation, with a minimum of 6" to 8" of side and top clearance and with sufficient access to controls and serviceable parts.

Provision should be made to prevent water damage in case of leakage. A catch pan with a minimum of ¾" drain line at least 2" in height may be installed under the storage tanks and sloped for proper drainage.

Electrical Supply

A 115-120 VAC receptacle is needed near the tank location to supply power to the solar pumps and controls. If a new receptacle needs to be installed, all connections should be made in accordance with local electrical codes by a qualified electrician or contractor.

The backup heating elements in the Electric Solar Storage Tank are supplied from 230-240 VAC circuit via a disconnect mounted near the storage tank. If a new connection is required, it should be made in accordance with local electrical codes by a qualified electrician or contractor.

Sensor Mounting at the Storage Tank

On most solar storage tanks, the temperature sensor is located behind an access cover near the bottom of the tank. To install the sensor*:

- Remove the sensor access cover to the tank.
- Remove the cover insulation until the shell of the tank is visible.
- Locate and remove nut from the threaded stud and place the temperature sensor on the stud.
- Secure the sensor to the tank with the nut.
- Make a small hole in the access cover and feed the sensor wire (from controller) through it.
- Connect the sensor wire from the controller to the sensor pigtail and secure with wire nuts or crimp connectors. **Note:** *it does not matter which wire is attached to the other.*
- Replace the insulation and sensor access cover.

*** Note:** *some Solar Storage Tanks may have the tank temperature sensor pre-installed. In these instances, it is only necessary to connect the sensor pigtail leads to the sensor wire from the controller.*

Plumbing

All piping run between the collectors and the drainback tank must be installed and secured to ensure proper drainage when the system is off. All horizontal runs from the collectors to the drainback tank should be sloped at a pitch of ¼" per foot minimum towards the tank, with piping laid out and secured to ensure no low points are created where water could become trapped.

All plumbing connections to the pressurized domestic water system should be made in accordance with local plumbing codes by a qualified plumber or contractor.

PART 2: Solar Hot Water System Installation

Application Tips for Retrofit Installations Using Existing Electric Storage Tanks

A DX drainback solar system can be retrofitted to an existing electric storage water heater by adding a collector array, a drainback reservoir (that incorporates a heat exchanger), two pumps and a system controller. In order to be able to connect the existing tank to the solar components, some modifications will need to be made to the existing water heater and plumbing connections.

Materials needed

- JB Weld (or similar epoxy)
- ½" PEX plug
- PEX / copper piping and fittings (*length of piping and type of fittings to be determined on site*)
- ½" copper tubing (about 10") (*needed for some tank configurations, see detailed description*)
- New cold-water dip tube (*needed for some tank configurations, see detailed description*)
- Teflon tape
- Solder
- Soldering Flux
- Emery cloth
- Copper or Brass NPT Threaded Nipple (*needed for some tank configurations, see detailed description*)
- Copper female NPT to sweat adaptor

Tools needed

- Pipe Flaring Tool (*needed for some tank configurations, see detailed description*)
- Pipe Wrench,
- PEX Cutting tool,
- PEX Crimping tool
- Drill with ¼" drill bit
- Tube cutter
- Propane torch and striker (*if using copper piping*)
- Tape measure

IMPORTANT NOTE:

These modifications are designed for electric storage water heaters that have cold-water inlets at the top of the storage tank using dip tubes. Electric storage water heater with cold water inlets entering the bottom of the tank from the side are NOT SUITABLE for these modifications.

Electric storage water heater with hot and cold top connections come in two configurations:

- A. Storage tanks with hot and cold top connection ports, and one anode (i.e., no additional anode)
- B. Storage tanks with hot and cold top connection ports, a primary anode, and an additional secondary anode (**Note:** *the secondary anode may be part of the hot water outlet port*)

The tank modifications and plumbing connections needed to utilize these two tank configurations differ slightly, and are summarized in Table 1.

PART 2: Solar Hot Water System Installation

Table 1: Tank and Plumbing Connection Modifications Needed for Existing Electric Storage Tanks
Used in Drainback Solar Water Heating Systems

TANK CONFIGURATION >	A. Storage tanks with hot and cold top connection ports, and one anode (i.e., no additional anode)	B. Storage tanks with hot and cold top connection ports, a primary anode, and an additional secondary anode
Tank and Plumbing Modifications Required	• MOD 1, • MOD 2A, • MOD 3, • MOD 4, and • MOD 5	• MOD 1, • MOD 2B, • MOD 4, and • MOD 5
Tank Port (location)	Function of Port in SHW System (refer to Figure 84 for additional details)	Function of Port in SHW System (refer to Figure 85 for additional details)
Cold water inlet (at top)	Solar hot water inlet to tank (from drainback tank HX)	Cold water inlet from mains to tank; and Solar cold-water outlet (to drainback tank HX)
Hot water outlet (at top)	Hot water outlet to house (no change)	Hot water outlet to house (no change)
Anode Port (at top)	Anode (no change)	Solar hot water inlet to tank (from drainback tank HX)
Drain Port (at bottom)	Cold water inlet from mains to tank; Solar cold-water outlet (to drainback tank HX), and Tank drain valve	Tank drain valve (no change)

CAUTION:

Before making modifications ensure that both the electricity and cold-water supply to the hot water tank are TURNED OFF, and that the tank is DRAINED.

Before soldering, ensure that there are NO FLAMMABLE MATERIALS in or around the work space, and that the space is WELL VENTILATED.

The following sections detail the modifications to an electric storage water heater, that are needed to convert it to a solar storage tank with backup heating. Complete the ones required based on the existing tank configuration as summarized in Table 1.

PART 2: Solar Hot Water System Installation

MOD 1 – Removal of the Cold-Water Inlet Heat Trap (for both tank types)

Complete the following steps:

- Disconnect or cut the existing cold-water inlet pipe to the tank cold-water inlet.
- Remove the cold-water inlet heat trap insert (if installed) from the top of the dip tube as shown in Figure 77.



Figure 77: Removing the heat trap insert from the cold-water Inlet

MOD 2A – Creating a Solar Hot Water Inlet Port (for tanks with no additional anode)

Complete the following steps:

- Remove cold-water inlet dip tube from the tank as shown in Figure 78.
- Shorten the existing dip tube using the steps described in section, **“MOD 2A & MOD 2B (continued) – Shortening the Dip Tube”**



Figure 78 Removing the Dip-Tube from the tank

MOD 2B – Creating a Solar Hot Water Inlet Port (for tanks with both primary and secondary anodes)

Complete the following steps:

- Remove the primary anode rod from the top of the tank. This anode port will be used for a new dip tube. Cathodic protection will continue to be provided by the secondary anode rod remaining in the tank.
- Purchase a new dip tube, and shorten it using the steps described in the section, **“MOD 2A & MOD 2B (continued) – Shortening the Dip Tube”**

MOD 2A & 2B (continued) – Shortening the Dip Tube (for both tank types)

Continue the modifications for 2A and 2B by complete the following steps:

- Shorten the dip tube by cutting it off just above the existing holes.
- Plug the end of the dip tube with the ½” PEX plug.
- Place the shortened dip tube on the outside of the tank as if it was installed in the tank as shown in Figure 79. Mark the location of the half-height of the tank on the dip tube.



Figure 79: Measuring the Half-height Tank Location

PART 2: Solar Hot Water System Installation

- f) Drill 4 x $\frac{1}{4}$ " holes straight through the dip tube (i.e., through both sides); one hole on the half-height line, and three evenly spaced below the half-height line and bottom end of the dip tube as shown in Figure 80.
- g) Re-install the modified dip tube into the tank. This dip tube will serve as the solar hot water inlet (i.e., connected from the drainback tank heat exchanger outlet).
 - a. For MOD 2A, install it in the cold-water inlet port
 - b. For MOD 2B, install it in the primary anode port



Figure 80: Shortened Dip Tube

MOD 3 – Modifications to the tank drainage valve / plumbing (for tanks with no additional anode)

Complete the following steps. Refer to Figure 82 for additional guidance on plumbing modifications.

- a) Remove the existing drain valve from the tank port at the bottom of the tank.
- b) Use the flaring tool set to flare the end of a length of $\frac{1}{2}$ " copper tubing and bend the flared copper tubing end downward at about a 45° angle, then cut the tubing so that the bent end is a short stub as shown in Figure 81. This bent tube will act as a dispersion tube to direct inlet cold water across the bottom of the tank.
- c) Thread a male-to-male NPT copper or brass pipe nipple (adapter) into the port at the bottom of the tank, and slide in the flared $\frac{1}{2}$ " copper tubing with the bent-end facing downward in the tank. Thread a female NPT to sweat copper/brass adaptor over the pipe nipple to lock the flared tube into the pipe nipple.
- d) Plumb in a "tee" that will serve as the solar cold-water outlet (i.e., connected to the drainback tank heat exchanger inlet).
- e) Plumb in a second "tee" and threaded fitting that will serve as the new drainage valve port for the storage tank.
- f) Plumb in a "90-elbow" that will serve as the new mains cold-water inlet to the tank.

Figure 81: Retrofit Dispersion Tube fabricated from $\frac{1}{2}$ " Copper Tubing

PART 2: Solar Hot Water System Installation

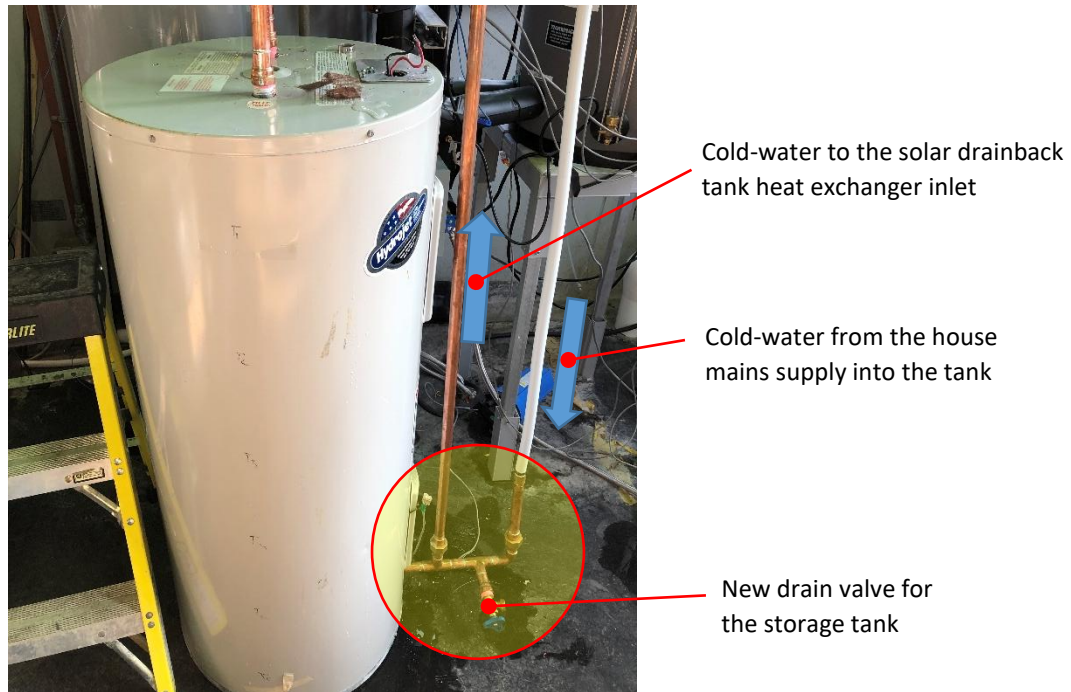


Figure 82: Modification to the Tank Drainage Valve / Plumbing

MOD 4 – Installation of a Storage Tank Temperature Sensor (for both tank types)

A new storage tank temperature sensor will need to be attached to the inner tank surface at the lowest accessible spot on the tank. This is accomplished by completing the following steps:

- Remove the access cover over the bottom thermostat control and heating element as shown in Figure 83.
- Move the insulation to expose the storage tank surface.
- Using epoxy (e.g. JB weld or similar) bond the thermistor to surface of tank, and secure in place until the epoxy has cured.
- Modify the access cover by making a small hole in it and feed the sensor wire (from the solar controller) through the hole.
- Connect the sensor wire from the controller to the sensor pigtails and secure with wire nuts or crimp connectors.

Note: it does not matter which wire is attached to the other.

DO NOT replace the insulation and access cover until after completing the next modification.



Figure 83: Removing the Bottom Access Cover to expose the Storage Tank Surface and Lower Heating Element Wiring

MOD 5 – Disconnection of the Lower Heating Element *(for both tank types)*

The lower tank electrical element needs to be disabled so that the bottom of the tank is heated by solar. This is accomplished by completing the following steps:

- a) Disconnect the two wires coming from the top thermostat. One wire will be connected to a bottom thermostat terminal and the second wire will be connected to a bottom heating element terminal.
- b) Once the two wires are disconnected, cap each one separately with an insulated wire nut to prevent shorting or grounding to metal surfaces.
- c) Replace / reposition the thermal insulation and re-install the access cover.

Balance of System Installation When Using an Existing Electric Storage Tank *(with modifications)*

After modifications have been completed, the cold-water mains supply can be re-connected to the tank, and the remaining solar components can be added to complete the solar DX drainback hot water installation.

The resulting solar hot water system configuration will be similar to one of the following:

- A. Figure 84 for existing storage tanks using a shortened dip tube installed in the cold-water inlet port as the solar hot water inlet.
- B. Figure 85 for existing storage tanks using a shortened dip tube installed in the primary anode port as the solar hot water inlet.

PART 2: Solar Hot Water System Installation

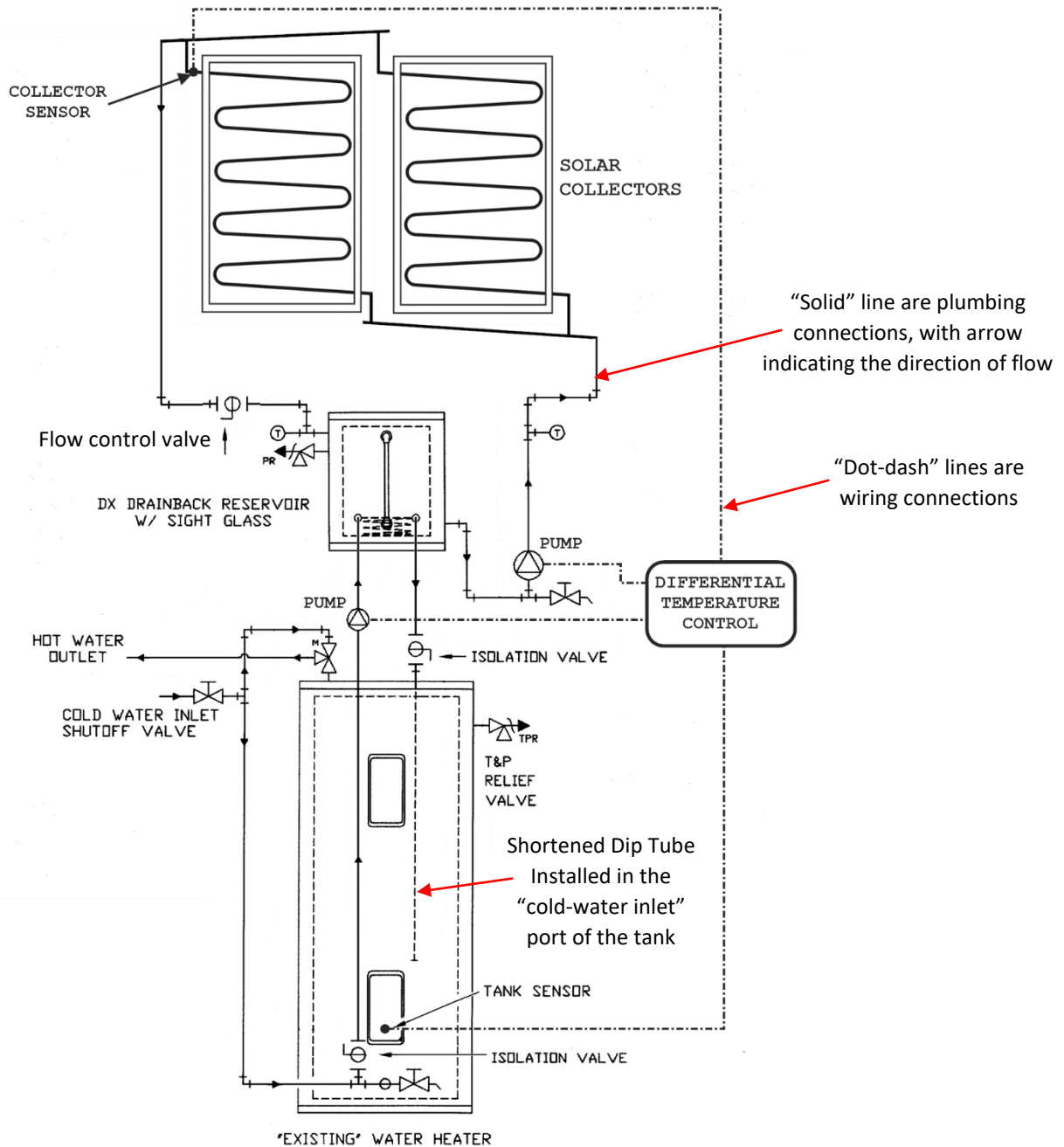


Figure 84: Schematic of a Solar DX Drainback System Using an Existing Electric Storage Tank with Modifications That Use the Cold-Water Inlet Port at the Top of the Tank as the Solar-Hot Water Inlet

PART 2: Solar Hot Water System Installation

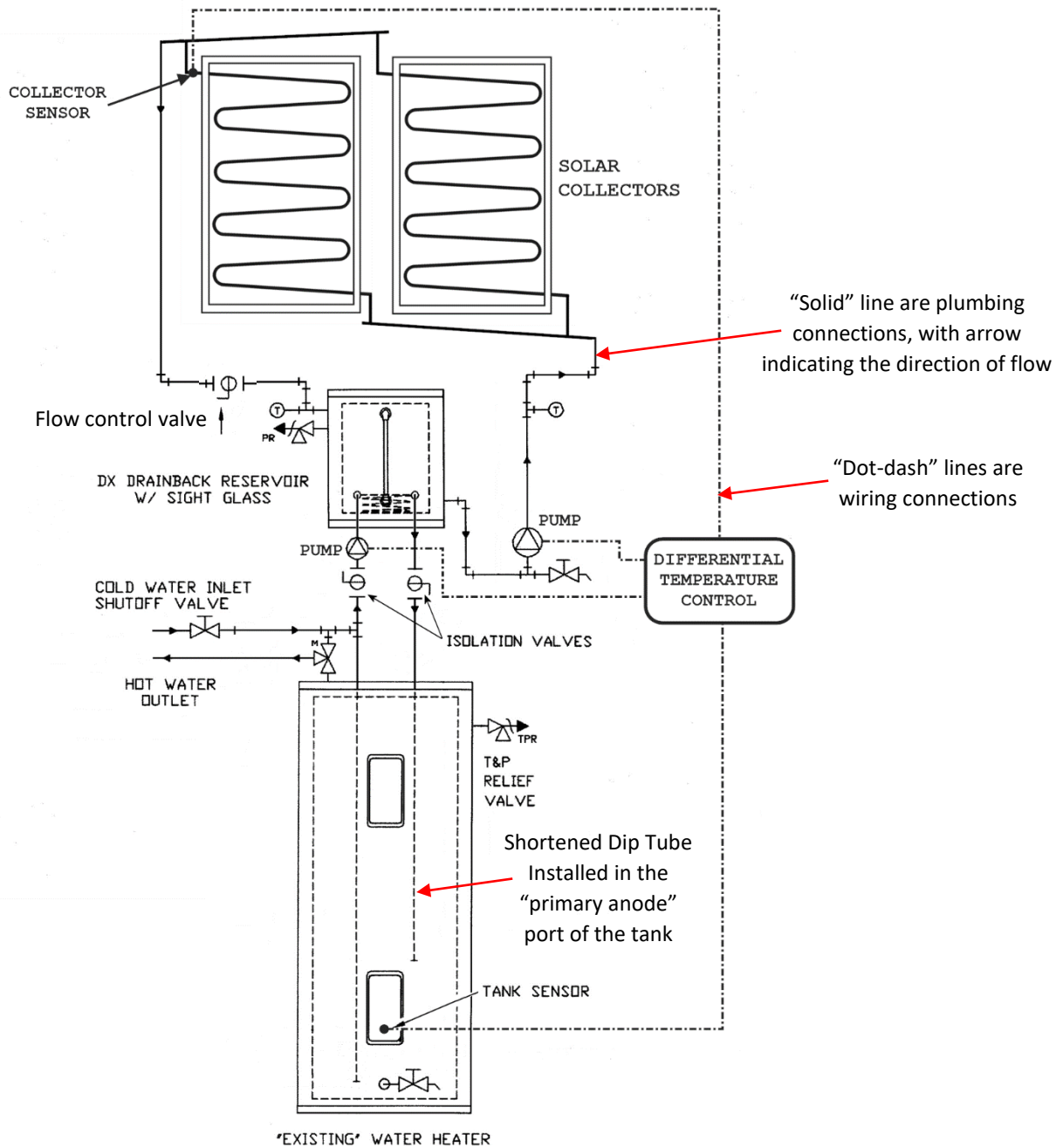


Figure 85: Schematic of a Solar DX Drainback System Using an Existing Electric Storage Tank with Modifications That Use the Primary Anode Port at the Top of the Tank as the Solar-Hot Water Inlet

System Fill and Commissioning

The system should be filled and commissioned according to manufacturer's instructions. The following provides general guidance on typical procedures to follow and is not intended to replace manufacturer's instructions.

Materials needed

- Drainback flush kit including:
 - Inhibitor and buffer additive (sentinel X100 or equivalent)
 - Descaler (if required, sentinel X200 or equivalent)
 - Cleaner (sentinel X400 or equivalent)

Tools needed

- Drainback pressure check kit
- Portable air compressor with gauge and regulator

Before filling the system, all plumbing should be checked for leaks. This can be done by connecting an air compressor to the drainback tank (being careful not to exceed pressure rating of the drainback tank, approximately 30 PSI).

The solar collector loop should then be flushed and cleaned in order to remove excess flux and debris that may have occurred during plumbing. This process should be done for existing systems to eliminate contaminants from the transfer fluid if needed, or after a repair has been made to the collector loop.

The system then needs to be filled according to the manufacturer's instructions.

Undertake all wiring and sensor connections to the controller according to the manufacturer's instructions.

Procedure to Achieve Optimum System Flowrate

This process can be followed to adjust the flow of the system to achieve as close as possible to the desired 2 GPM flowrate, which will maximise the outlet temperature of a 2 collector, parallel system (1 GPM for a series 2 collector system). Maximising the outlet temperature of the solar collectors will result in a higher delivered temperature to the storage tank, leading to a more efficient system (and less use of electric auxiliary power).

This process should be undertaken on a clear sunny day as close to solar noon as possible with the system running:

- a) Ensure the system has been operating for some time. It will likely have turned on earlier in the morning. The solar loop pump and domestic hot water circulator pump should be flowing.
- b) Using the temperature gauge installed on the return plumbing line to the drainback tank from the solar collectors, take note of the temperature reading on the gauge.
- c) Gradually turn the flow control valve (plumbed into the solar collector loop return line (as shown in Figure 76, Figure 84, and Figure 85) ball valve counterclockwise to 45° (half way between fully open and fully closed). This will slow down the flow in the solar loop, resulting in a quieter system. This is the starting position for this procedure. Take note of the temperature reading on the gauge. If the temperature reading is > 60°C, stop here. If the temperature reading is < 60°C, continue to step d.
- d) Under ideal conditions, a solar loop return temperature of at least 60°C should be attainable (this depends on the temperature of solar loop supply water, but 60°C should be attainable once the system has been running for a couple hours). To achieve this, slow down the flow through

PART 2: Solar Hot Water System Installation

the solar collector loop by continuing to turn the ball valve in small increments counterclockwise (i.e., incrementally closing) and observe the temperature on the gauge while doing so. Pause for several minutes after each increment of closing. This process will further slow down the solar loop return flow, causing the temperature to gradually increase.

- e) Continue the process of incrementally turning the ball valve and watching the temperature on the gauge. The ball valve will likely need to be turned somewhere between 45° (half way closed) and 90° (fully closed) to achieve the degree of flow desired.
- f) Mark the position of the ball valve handle on the surrounding insulation or other location for future reference.

NOTE:

NEVER FULLY CLOSE THE SOLAR COLLECTOR LOOP RETURN LINE BALL VALVE. DOING SO WILL CUT-OFF FLOW IN THE SYSTEM, WHICH WILL “DEAD-HEAD” AND DAMAGE THE PUMP.

References and Resource Materials

1. Natural Resources Canada, *"Solar Ready Guidelines for Solar Domestic Hot water and Photovoltaic Systems"*, version 1.1, 2013. *(PDF available online; Web search title to find website).*
2. Natural Resources Canada, *"Photovoltaic Potential and Solar Resource Maps of Canada"*. *(Available online; Web search title to find website).*
3. Truss Plate Institute of Canada, *"Solar Ready Truss Design Procedure, TPIC Technical Bulletin #7"*, Revised March 12, 2020 *(PDF available online; Web search title to find website).*

Appendix 1: System Demonstration Installation Examples

Demonstration 1

Configuration: Series, Wall mount, New Solar Water Heater (80 gallon with electric auxiliary)



Figure 87: Front view of demonstration installation showing solar thermal collectors at Wahkohtowin Innovation Centre, Chapleau, Ontario, 2021.



Figure 88: Side view of demonstration installation showing solar thermal collectors at Wahkohtowin Innovation Centre, Chapleau, Ontario, 2021.



Figure 86: Front view of demonstration installation showing drainback tank, controller and new electric solar storage tank at Wahkohtowin Innovation Centre, Chapleau, Ontario, 2021.

Demonstration 2

Configuration: Series, Roof Mount, New Solar Water Heater (80 gallon with electric auxiliary)



Figure 90: Top view of demonstration installation showing solar thermal collectors at Missanabie Cree First Nation, May 2022.



Figure 89: Front view of demonstration installation showing new electric solar storage tank, drainback tank and controller at Missanabie Cree First Nation, May 2022.

Demonstration 3

Configuration: Series, Roof Mount, New Solar Water Heater (80 gallon with electric auxiliary serving as preheat to propane large storage tank)



Figure 91: Front view of demonstration installation showing solar thermal collectors at Chapleau Cree First Nation, Mukeso House, September 2022.