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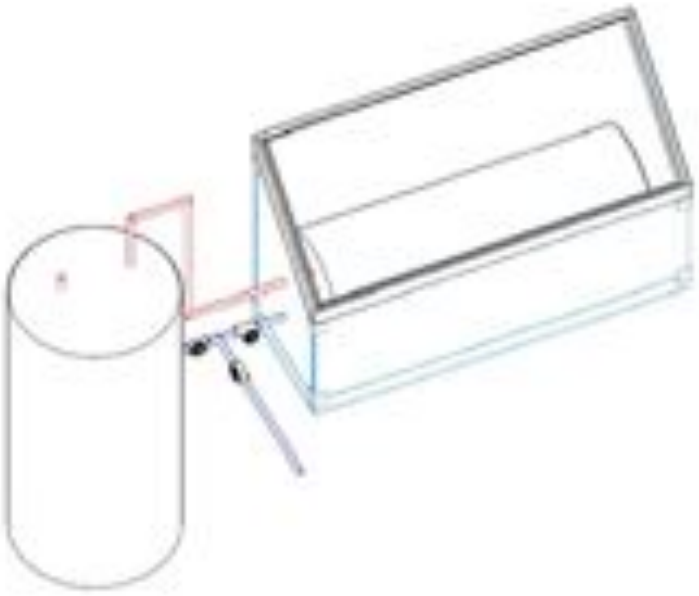
Do It Yourself
Thermal Solar Hot Water



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Section 6

Do It Yourself

Thermal Solar Hot Water

Constructing Your Solar Batch Collector

This guide provides plans for a passive-direct solar batch water heater, which is the simplest form of solar water heating system. The system outlined in this guide works by diverting water from your home's conventional tank water heater to the solar batch collector where the sun's rays heat the water before it returns back to your home's conventional water heater tank until use. When climactic conditions are favorable, the batch system heats the incoming cold water before it enters your home's conventional water heater, decreasing or eliminating the use of gas or electricity to heat water for your home. When outdoor conditions are cold and/or cloudy, your home's conventional water heater supplements the solar system to ensure hot water is available 100% of the time.

Benefits of this system include:

- It is relatively inexpensive and easy to build.
- It works with your current water heater to provide hot water at all times.
- It requires minimal maintenance.
- It can decrease or even eliminate your monthly water-heating bill!

The batch collector is simple to build. In essence, it consists of a black water tank inside a south facing wooden box with a glazed top. A cold water line runs into the box and a hot water line runs out of it. In addition to these essential elements, other optional components include gauges and valves to monitor system performance and ensure optimal operation and insulation for the collector box and water pipes to increase efficiency.

With this simple description, a proficient Do-It-Yourselfer could probably construct a successful batch solar water heater. The system outlined in this guide, however, is designed with a specific set of components to optimize performance and to minimize costs. Each system will be

slightly different, but if you decide to adjust your system's design, be sure all pieces of the new design fit together before beginning construction. Two variable design details about this guide's plans are discussed below.

- **Optimal Solar Orientation.** The pitch of the glazed portion of the solar collector is 40o. As a rule of thumb, the optimal solar orientation angle is equal to the location's latitude. The 40o angle of the design in this guide is a good average for the United States, but
- can be altered to the latitude of your exact location.
- **•ize of the Batch Collector.** The plans in this guide accommodate tanks up to 64" long and 21" wide. These dimensions should accommodate most water tanks of 50 gallons and less. If the tank you use is larger or significantly smaller, adjust the size of your collector box.
-

Before You Begin

Before you begin construction of the solar batch water heater outlined in this guide, there are a few steps you should take to determine the compatibility of your home with the solar batch system you intend to install.

1. Requirements and Recommendations for Your Physical Property

   Required: South-facing location for the batch collector. Why? Solar water heating depends on direct solar gain to operate, and, in the northern hemisphere, direct solar gain comes from the south. In order for your solar system to operate effective, the collector must be south facing.

Recommended: South-facing location is free of shade and obstructions. Why? For optimal performance, collector needs to receive near-constant sunlight during daytime hours. This means that the collector should not be shaded throughout the course of the day. For methods to ensure that the collector remains unshaded throughout the course of the day, see SITING in the Installation section of this guide.

Required: Conventional tank water heater system.

Why? The design outlined in this guide is for a solar batch system that feeds into a conventional tank water heater. As a DIY project, this design is manageable and affordable. Other types of solar hot water systems and strategies for integration are beyond the scope of this guide.

Recommended: Conventional tank water heater is electric. Why? Your solar batch water heater will perform slightly better if your home's conventional water heater is electric, versus gas, but either type of conventional system will work.

Solar water heating takes advantage hot water rising and cold water sinking. This is called stratification. Electric water heaters encourage stratification within the conventional water heater tank because the electric heaters are located on the top third of the tank. The water at the top of the tank stays at the top because it is warmer than the cool unheated water at the bottom of the tank. In a gas system, the water is heated form the bottom of the tank, which decreases stratification.

Recommended: Conventional tank water heater (indoor) is located near solar collector (outdoor). Why? A large amount of the water's heat is lost in the pipes connecting the solar collector to the indoor water heater tank. The shorter the pipes between the

outdoor collector and indoor tank, the more efficiently the solar system will perform.

2. Understanding Performance Limitations – Climate

   Beyond the requirements necessary to install your batch system, you should understand the performance limitation of your solar water heater based on your location's natural climate. Unfortunately, there is no formula to calculate your system's expected performance in a given area, but common sense will give you a good idea of the level of performance you can expect.

   Solar water heating works best in generally hot and sunny areas. For colder areas, performance will be diminished, and in areas prone to freezing temperatures, the solar water heater may need to be inactive during winter months. While solar water heating systems can be protected from damage caused by freezing temperatures, it is important to recognize that the system will not produce abundant hot water in adverse conditions.

3.

Materials Lists

Solar Batch Collector

1. Recycled Water Heater Tank
2. 3 Sheet of 4' x 8' x 1⁄2" Pressure Treated Plywood
3. 3 Sheets of 4' x 8' x 2" Foil-faced Isocyanurate Insulation (e.g. Thermax). DO NOT USE PLASTIC/POLYSTYRENE INSULATION.
4. 4.22' of 2" x 4" Pressure Treated Lumber
5. 1 Roll of 2" Reflective Tape
6. 1 Box of 3" Lag Screws
7. 8 Metal, Wood-to-Wood Corner Connectors
8. 1 Sheet of Glazing*
9. 18' of 1" wide Heat Resistant (non-plastic) Weather Stripping
10. 18' of Aluminum Flashing

* Glazing can be glass or plastic and must be sized to fit the top of the batch collector. Some good options include a recycled sliding glass door panel, Filon solar plastic Glazing, Sun- Lite Glazing panel, Kawall plastic panel.

Construction

Part 1 - Prepping the Tank

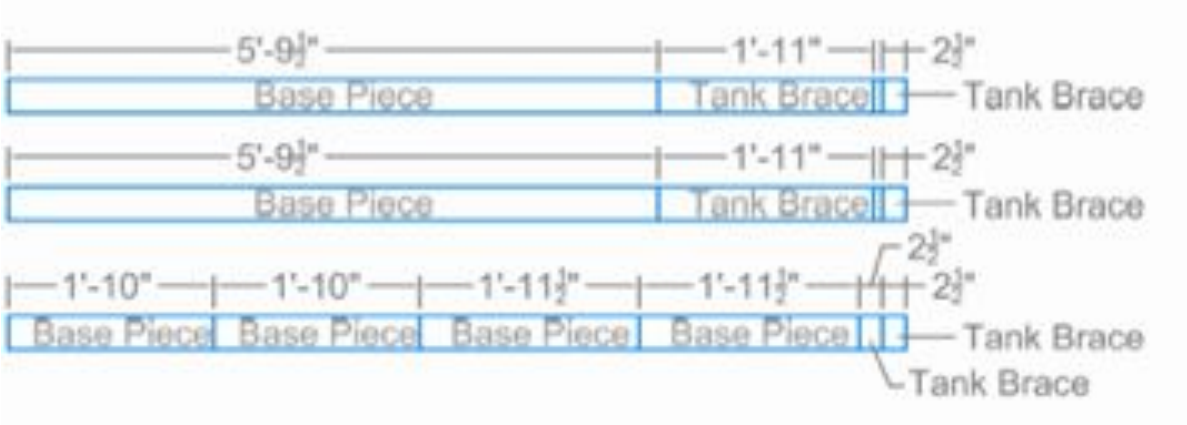
1. Strip the water heater tank. Remove outer sheet metal shell, insulation, thermostat, nipples, and wiring, but do not remove the anode rod, electrical elements, or drain valve.
2. Test the tank for leaks. Plug all but two inlet holes at the top of the tank. Use 3⁄4" galvanized plugs to plug inlet holes. Fill the tank through one of the inlet holes using a garden hose. Add water until it spills out of the top of the tank. Check for water leaking anywhere except the unplugged hole on the top of the tank, especially around the drain valve. Drain the tank using drain valve at the bottom of the tank and let dry.
3. Check the tank's anode rod. The anode rod is the removable chemical component in a water tank that reacts with minerals in hard water to minimize scale buildup in the system plumbing. The anode rod should be in good condition and should be replaced regularly throughout the life of the system. You should also check and replace the anode rod in your home's conventional
4. Check for rust in the tank. Remove rust with sandpaper as necessary.
5. Paint the tank with a flat black exterior and temperature tested spray paint. You can also add a selective surface to the side of the tank that will face the sun. A selective surface will readily absorb solar energy but readmit only a small amount. An example of a spray-applied selective surface is Selective Solar.
6. Check the drain valve. It should be closed.

Part 2 – Construct the Batch Collector

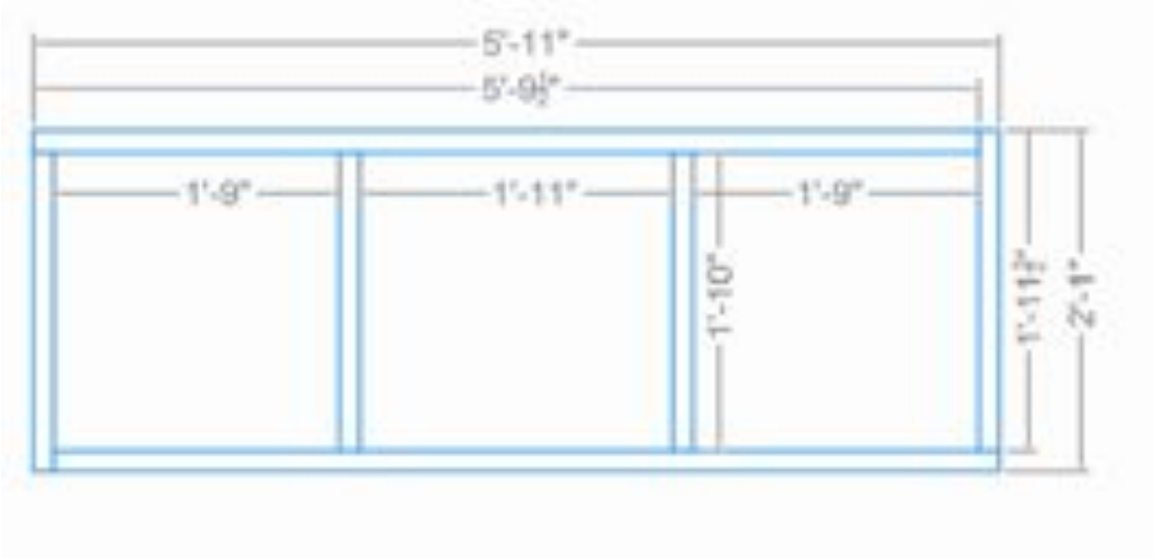
This guide outlines a batch collector that will accommodate tanks up to 64" in length and 21" in diameter, but you can adjust the collector design to fit your water tank.

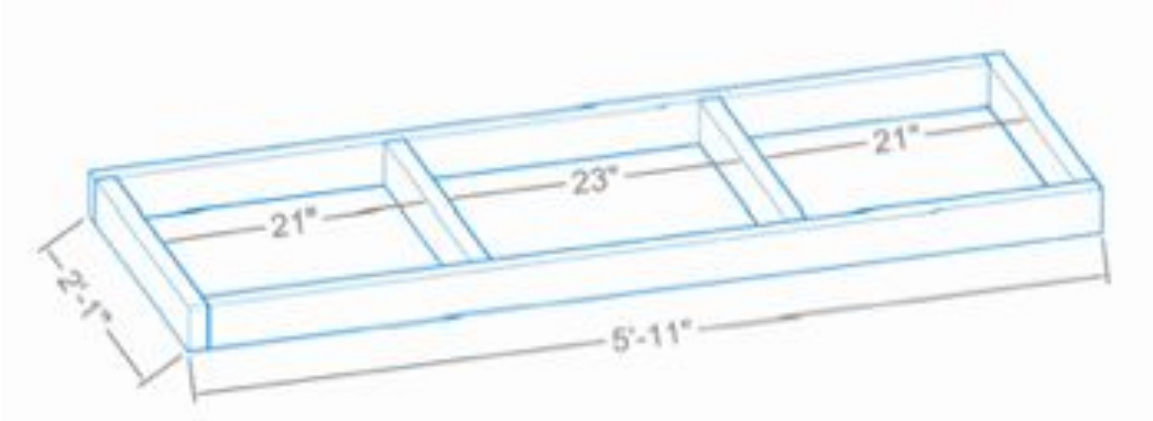
1. Cut 2" x 4" lumber into base and tank brace pieces according to cutting diagram.

2 x 4 Cutting Diagram (8 ft. in length)

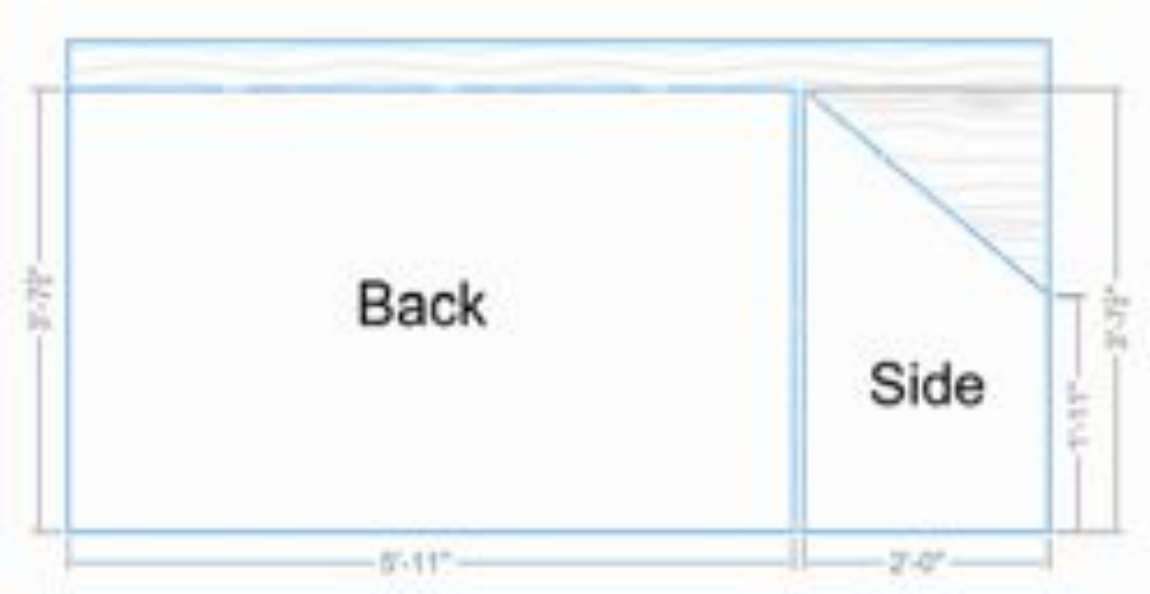


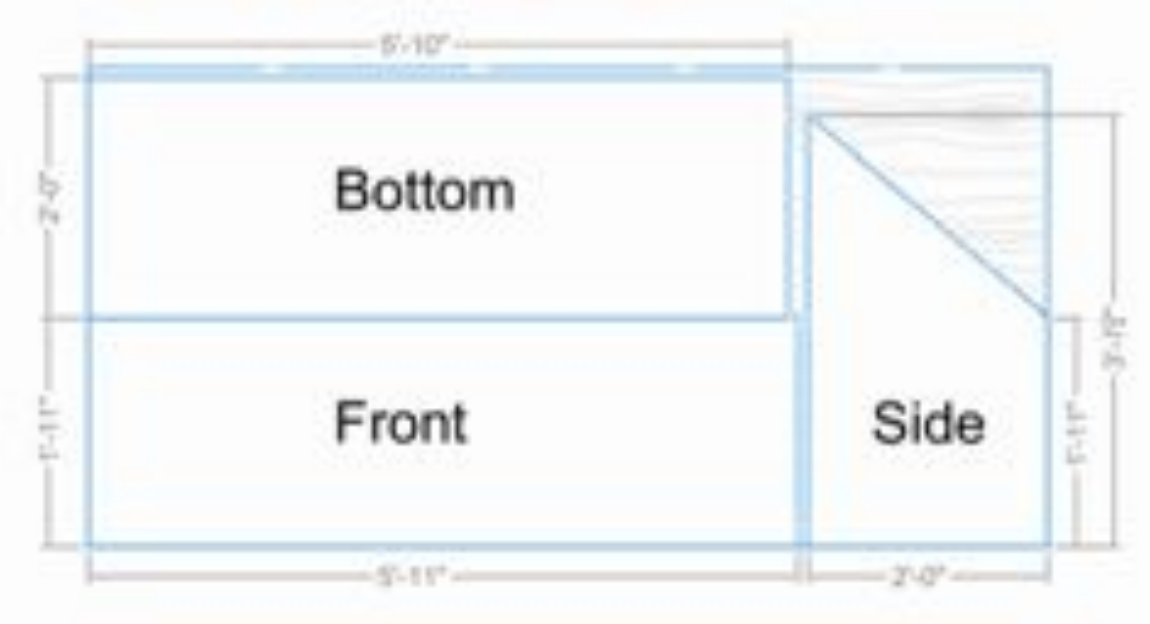
2. Assemble base using 3" lag screws. Keep in mind that the actual dimension of "2 in. x 4 in. " lumber is 1.5 in. x 3.5 in.



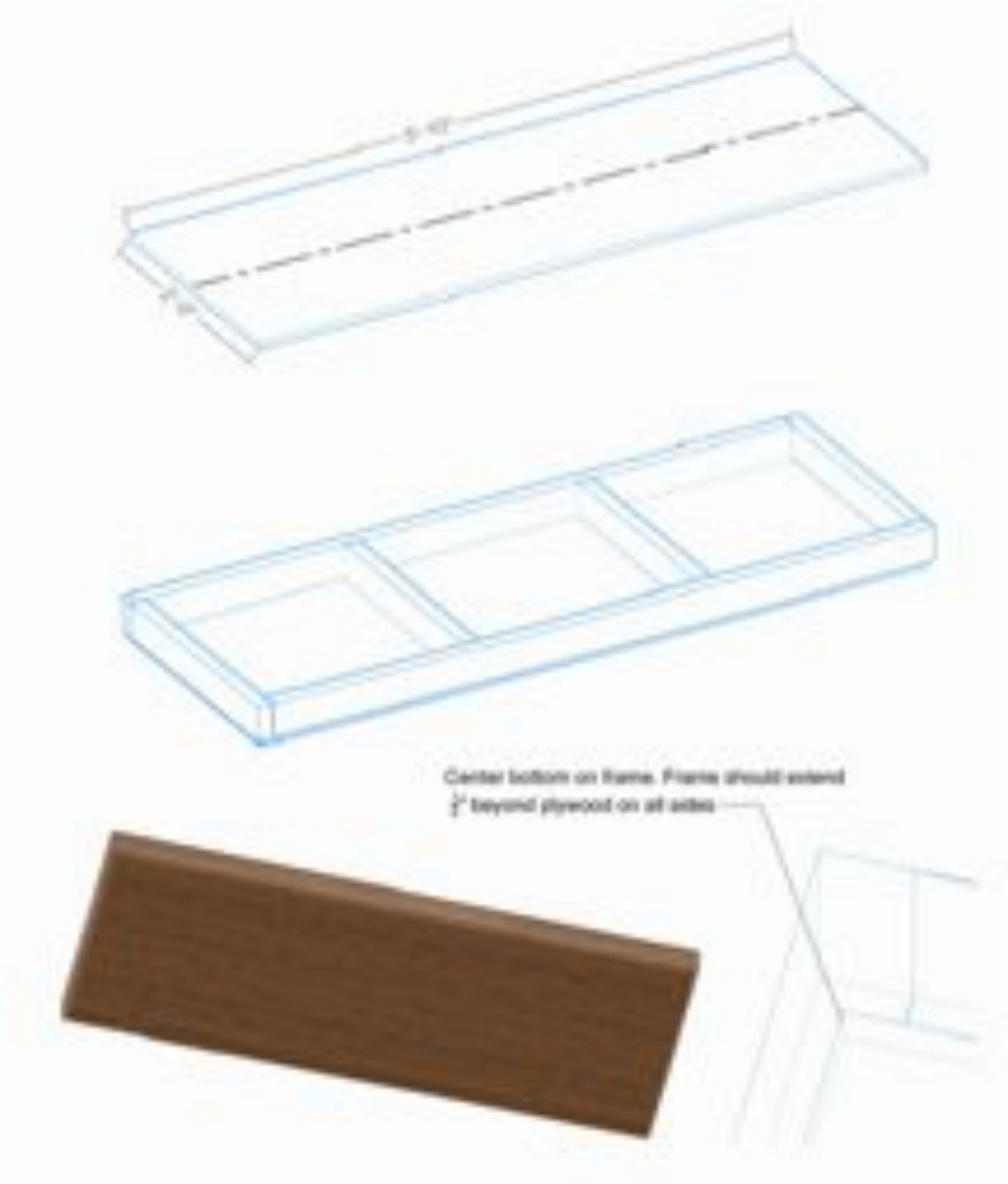


3. Cut the 4' x 8' x 1⁄2" plywood sheets according to the cutting diagrams below. Often the lumber yard at which you purchase the plywood will cut the wood for you if you have the cutting diagram.

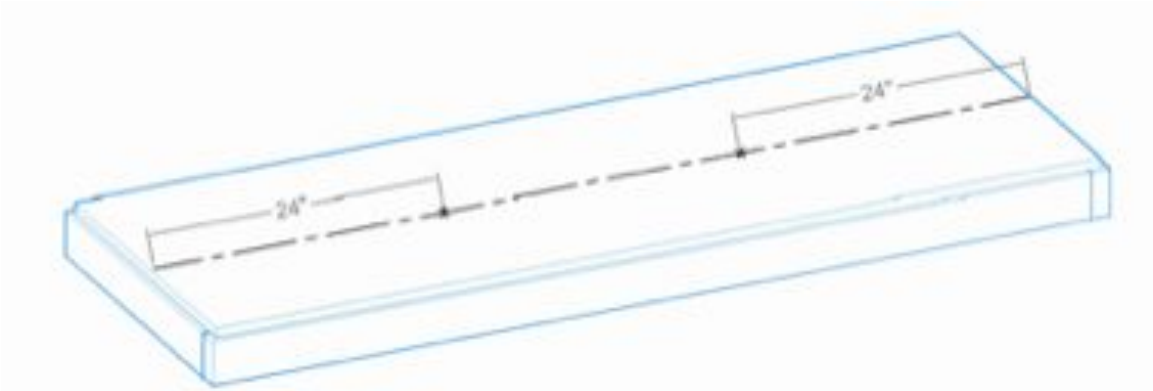




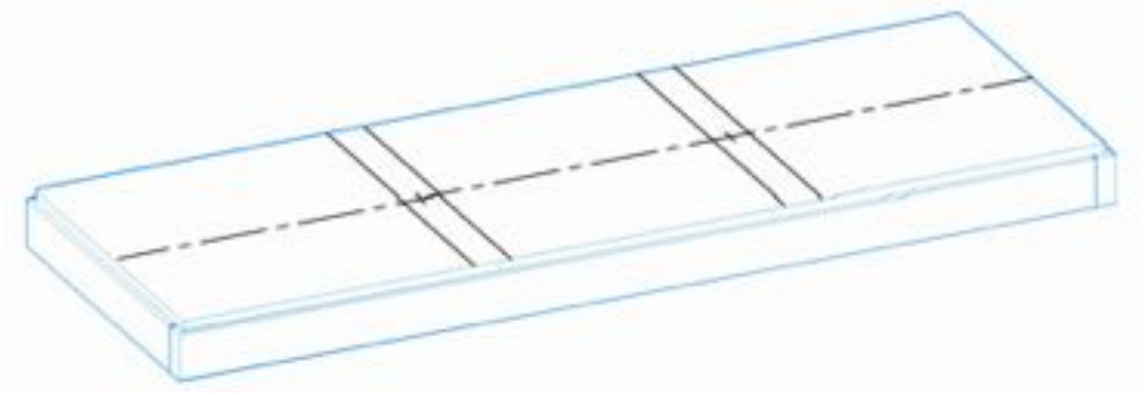
4. Find the "Bottom" plywood piece. Draw a centerline down the length of the piece. Attach the plywood piece to the 2" x 4" lumber base with lag screws. Make sure the plywood piece is centered on the base. The base should extend 1⁄2" beyond the plywood on each side. See sketch below.



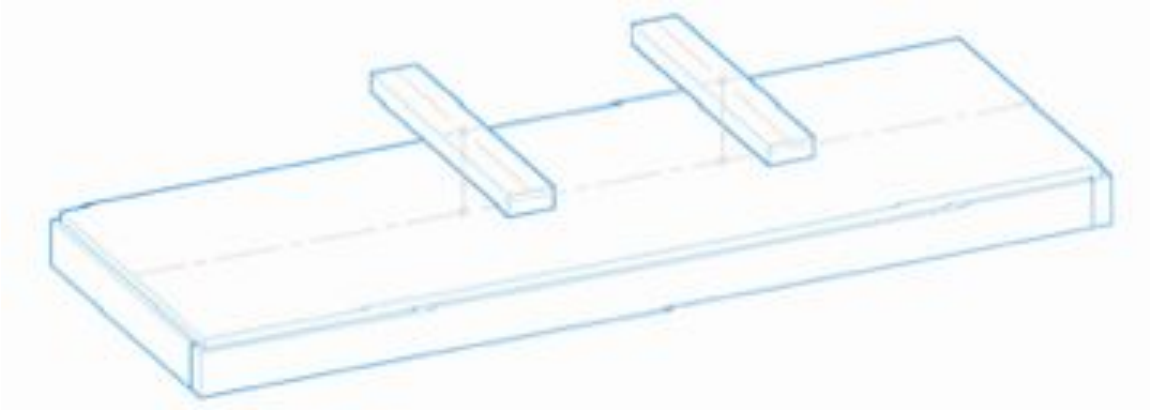
5. Starting at either of the short ends of the "Bottom" plywood piece, measure 24" along the centerline toward the center of the piece. Mark this spot. Do the same measurement and marking from the opposite end.

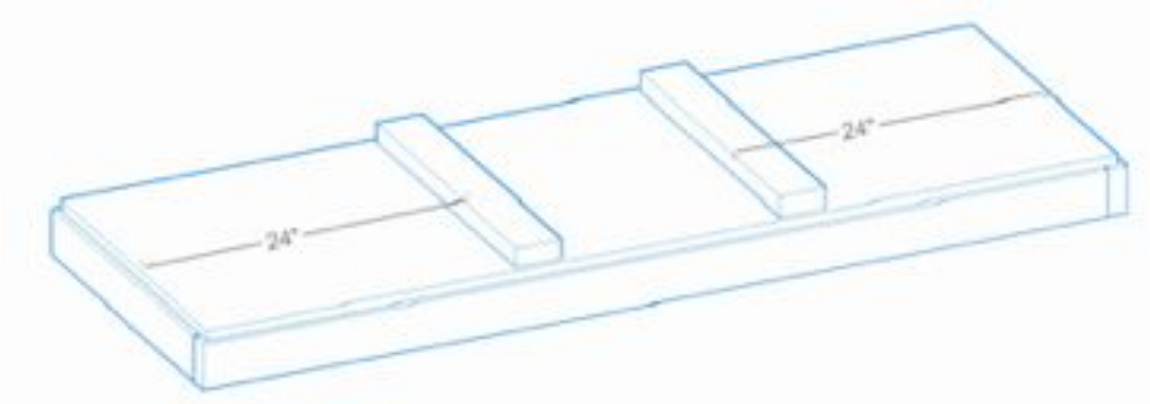


Note: To aid in placing the tank braces, measure 11/4" off of each side of the mark. Use a carpenter or speed square to mark the position of the braces on the bottom plywood sheet as shown.

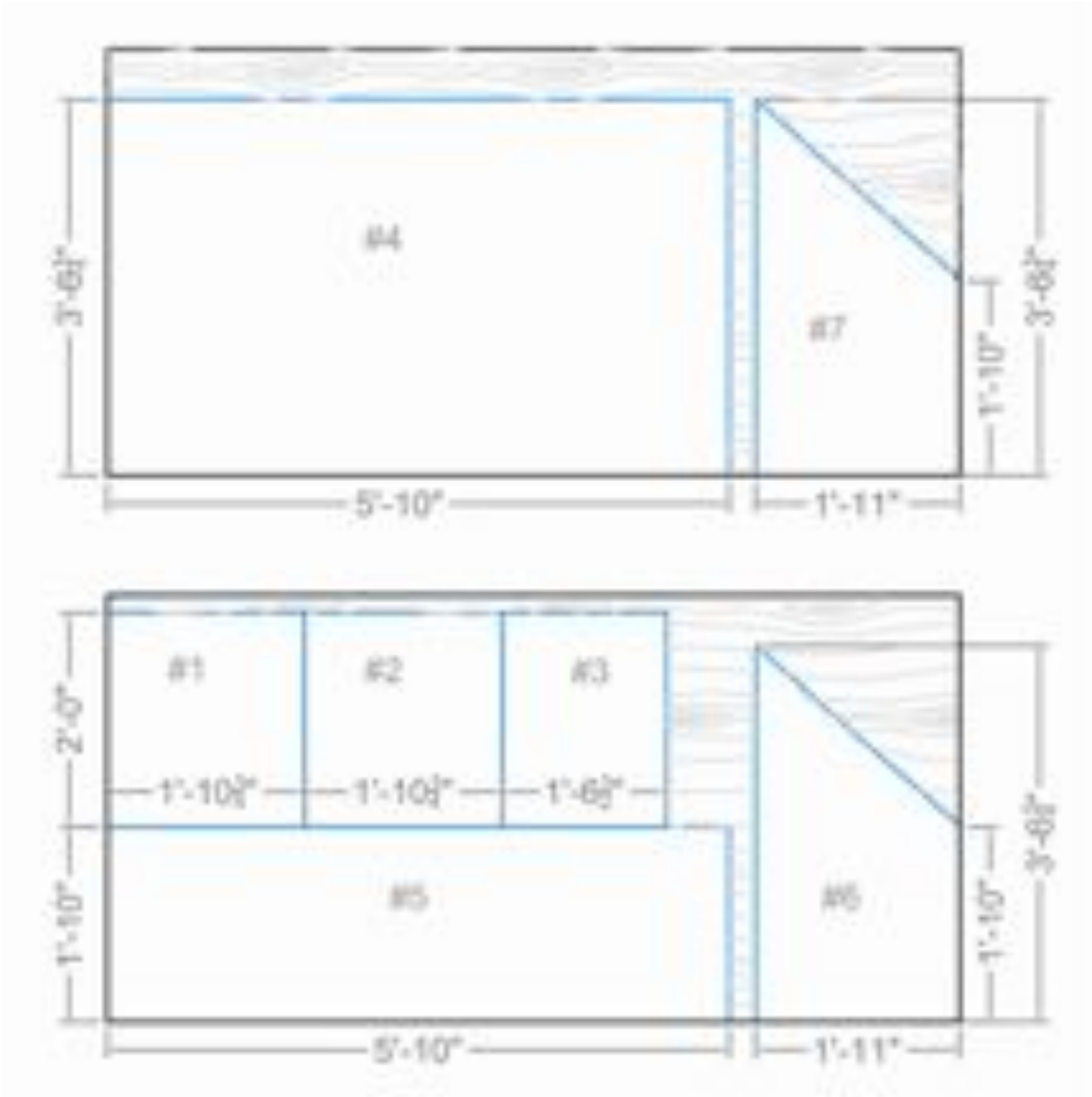


6. Attach the large brace pieces. Start by marking the center of the two 24" pieces of the tank braces. Align the center markings on the two 24" pieces with the two markings on the centerline of the "Bottom" plywood piece. Using 3" lag screws, attach the two 24" tank brace pieces to the "Bottom" piece as shown in sketch. Keep track of remain 2 1⁄2" tank brace piece from step 1.

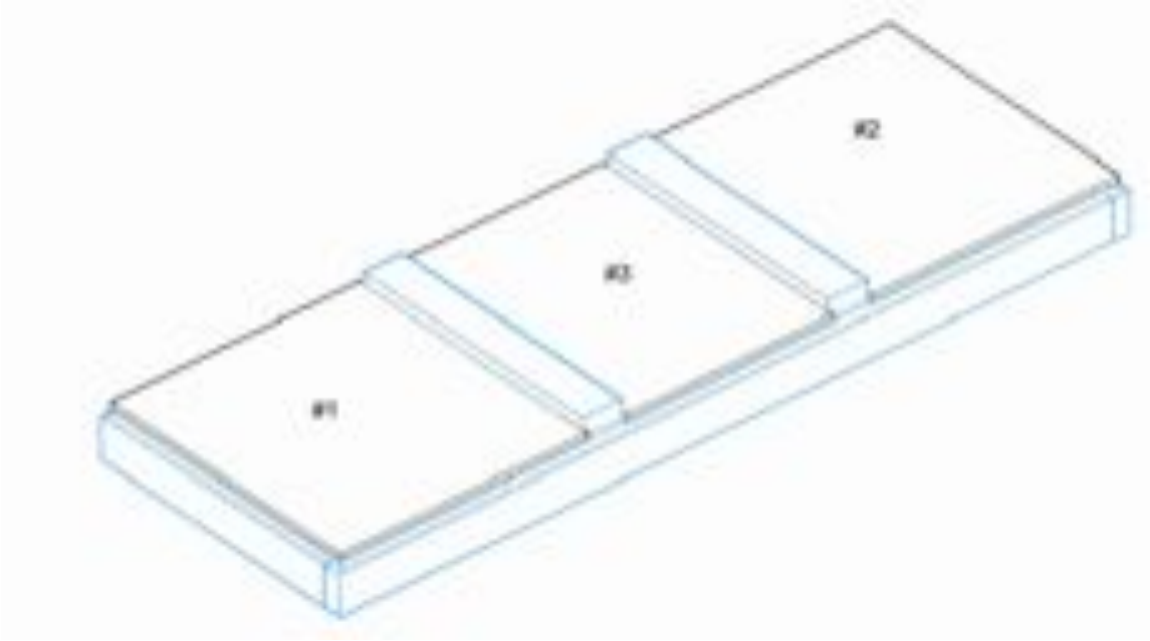




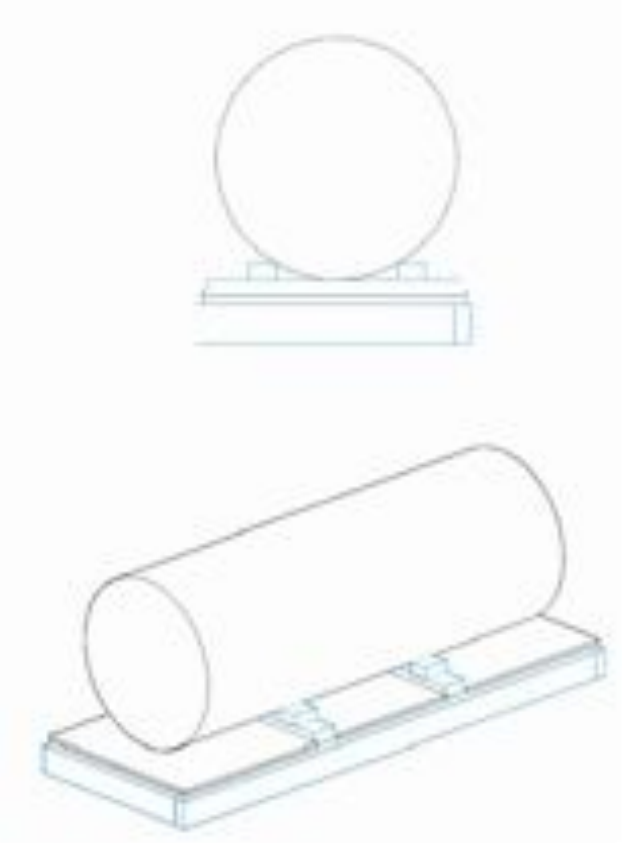
7. Cut 4' x 8' x 1⁄2" insulation sheets according to cutting diagrams below.



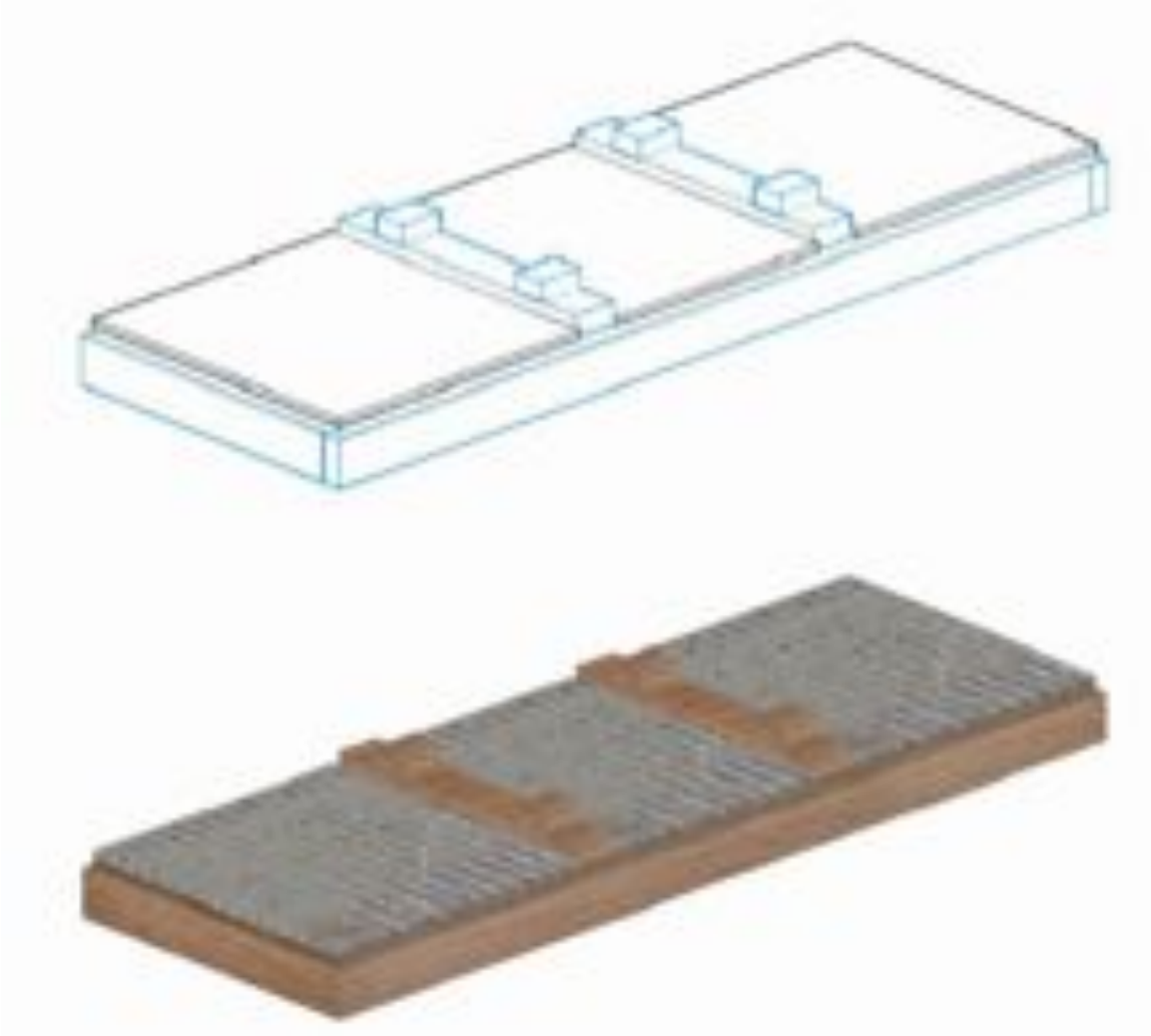
8. Attach insulation pieces #1, #2, and #3 to the "Bottom" plywood piece between the tank braces.



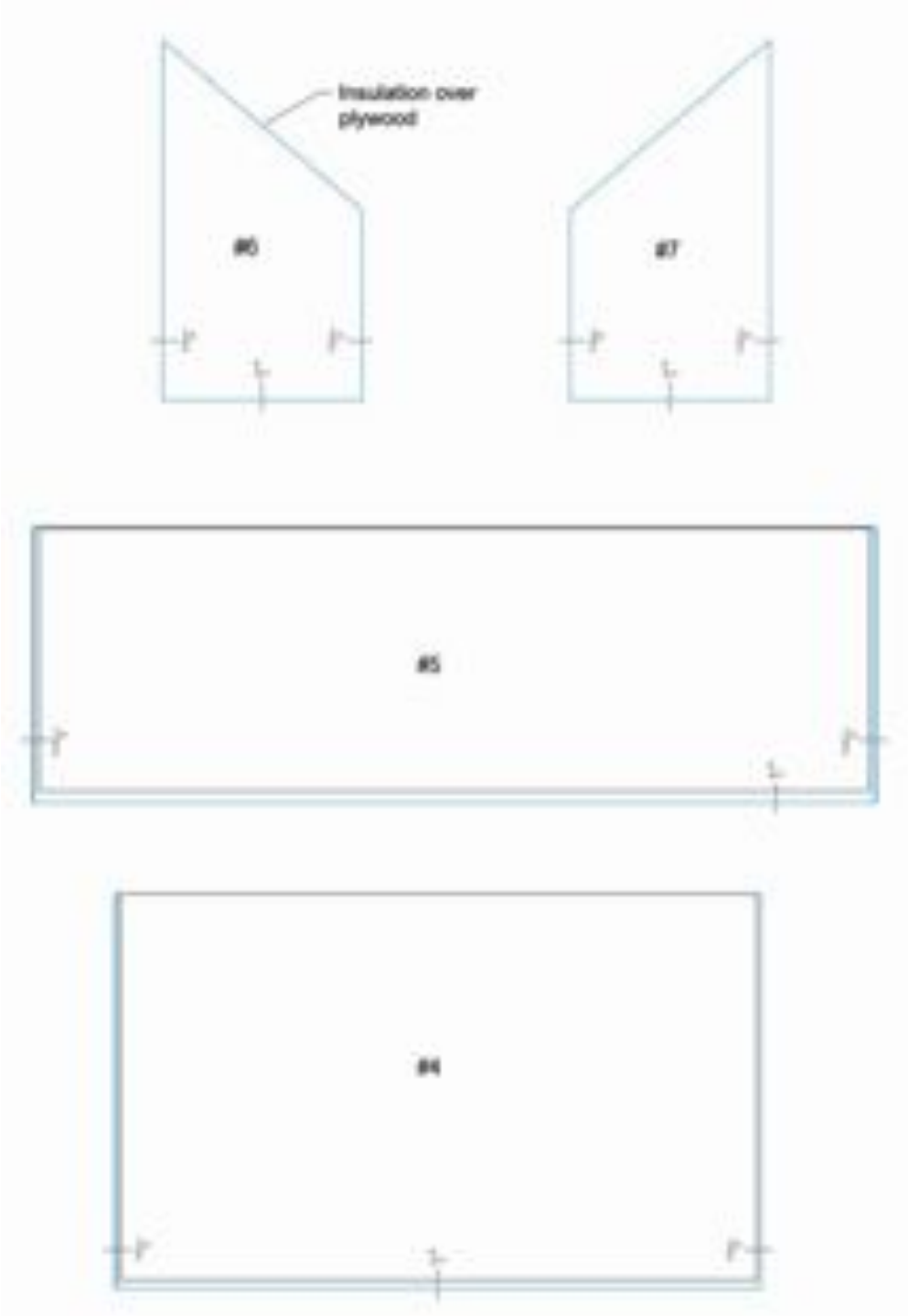
9. Find positioning for the remaining 2 1⁄2" tank brace pieces on the 15" tank brace pieces. Start by placing the water tank on the 15" pieces attached the "Bottom" plywood piece. THE WATER TANK MUST BE CENTERED ON THE 15" TANK BRACE PIECE. THE TANK SHOULD CONTACT THE 15" PIECES AT THE CENTERLINE OF THE PIECES MARKED IN STEP 6. Holding the tank in place with one had, use your free had to place the 2 1⁄2" pieces of lumber such that they rest on top of the 24" piece and in contact with the tank, which should still be centered on the two 24" pieces. Mark the position of the 2 1⁄2" brace pieces on the 24" pieces. See sketches.

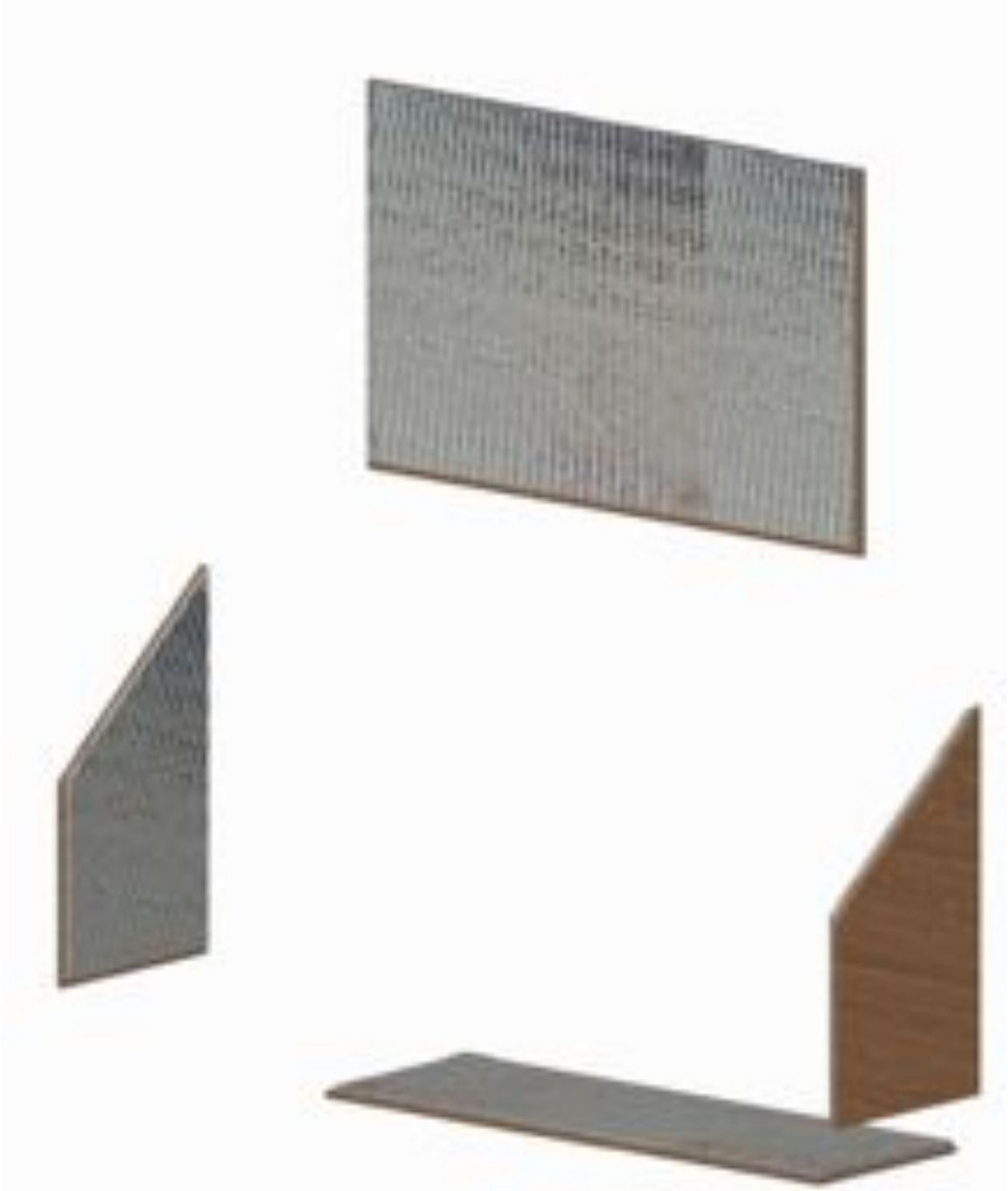


10. Remove the water tank from the brace pieces. Attach the 2 1⁄2" pieces to the 24" pieces according to the place markings you made in step 9.



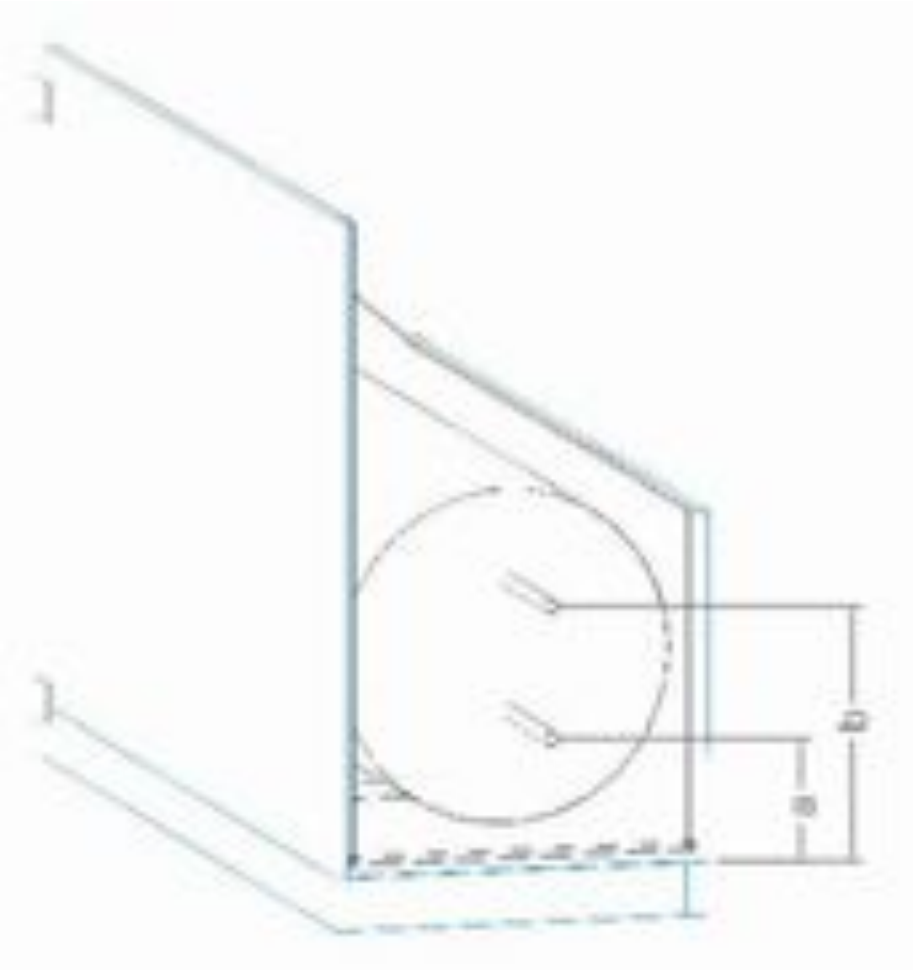
11. Attach insulation pieces #4, #5, #6, and #7 to the walls of the batch collector. Be sure they are aligned correctly. See sketch.



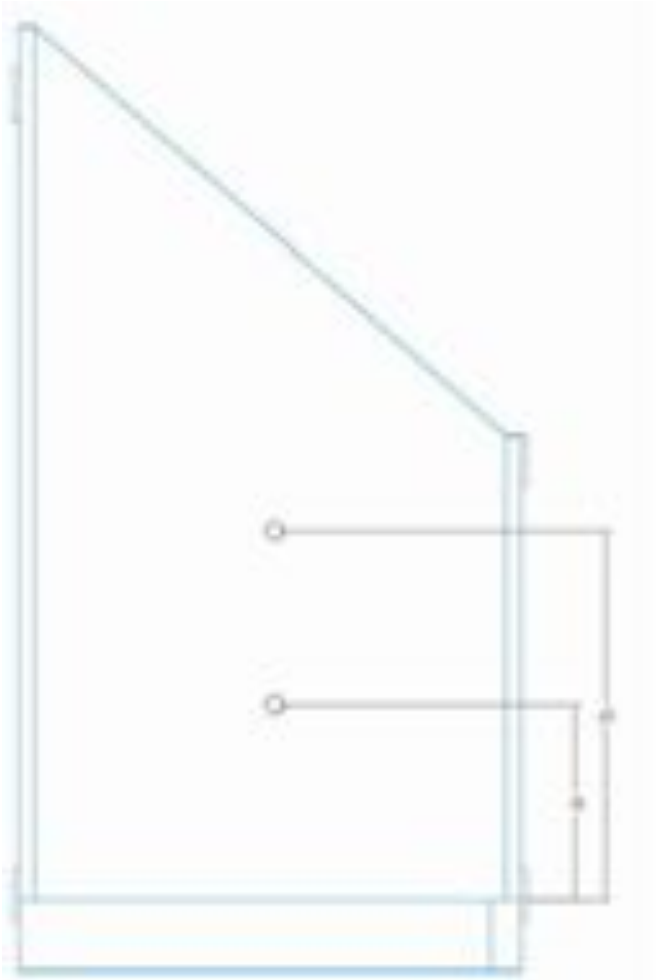


Assemble batch collector box. Attach "Front" and "Back" walls first. Then add only one "Side" wall. Leave the final "Side" wall for later. Use wood-to-wood connectors on exterior corners. Everything should fit together tightly.

12. Seal insulation joints inside the collector with 2" reflective tape.
13. Place tank back on assembled tank braces such that the inlet holes on the tank are at the end with the unattached "Side" wall. The braces should now prevent the tank from rolling. Rotate the tank so that the two unplugged inlet holes are aligned vertically. Install two 6" galvanized nipples into two open inlet holes. Measure the vertical distances a and b on sketch. These are the distance from the top of the 2" x 4" base to the centre of the protruding galvanized nipples. Write down distance a and b for use in step 15.



14. Place the unattached "Side" wall and insulation down on the ground. Find the horizontal center of the "Side" wall along the bottom edge. From this point, vertically measure and mark the two vertical distances for the inlet holes.
15. Drill 3⁄4" holes in unattached "Side" wall where marked.
16. Attach final "Side" wall. Galvanized nipples should protrude through holes in "Side" wall. Install grommet or some other airtight seal where galvanized nipples enter the collector box.



17. Seal "Side" wall insulation joints with reflective tap.
18. Install 1" wide weather stripping along top edges of all four sides of collector box. Place glazing to top of box. Be sure that glazing forms a tight seal with weather stripping. Multiple layers of weather stripping may be required on certain sides or in corners to achieve airtight seal.
19. Seal glazing-to-plywood joints with aluminum flashing.

Installation

1. Siting Your Solar Batch Collector

There are three important factors to consider when determining the ideal location for your solar water heater: 1) the orientation of the collector, 2) obstructions between the collector and the sun's path, and 3) the distance between the collector and the home's conventional tank water heater. This section will help you site your solar water heater for maximum efficiency and performance.

Orientation: The most important factor when siting your solar water heater is to ensure it is optimally oriented. The solar collector should be oriented as close to due south as possible. If you cannot orient your collector due south for some reason, the collector should be oriented not more than 30 degrees east or west of due south. First, you will need to determine true south, which is different than magnetic south which you find with a compass. To determine true south use either the Compass Method or the Solar Noon Method described below.

- **The Compass Method**

  The compass method for finding true south adjusts for the difference between magnetic north and true north. The difference between magnetic north and true north is called magnetic declination, and it differs by geographic location.

  To determine true north using the compass method, first, visit the website below to determine the magnetic declination for your location. Declination will be given in the form xo East or West of North. Once you know your locations magnetic declination, measure magnetic north on your compass, and then adjust the north reading by your areas solar declination. This will give you true north. True south will be 180 o different – or directly opposite – true north.

http://www.ngdc.noaa.gov/geomagmodels/struts/calcDeclination

- **The Solar Noon Method**

  The solar noon method for finding true south is based on the principal that, in the northern hemisphere, the sun is due south at solar noon. This means that all shadows run true north-south at solar noon. But solar noon is not the same as noon standard time.

  In order to determine true south via the solar noon method, use the website below to determine the standard time that correlates with solar noon on any day of the year. You will need to know your location's approximate latitude, longitude, and time zone. Then, go outside at the standard time which correlates with solar noon on any given day, and mark the orientation of the shadows. The shadows will run north south. The point at which the shadow meets the object which casts it – i.e. the bottom of the shadow – will be the southerly end.

  http://www.solar-noon.com/

Obstructions: After orienting your collector true south, the most important factor for siting your solar collector is the absence of obstructions. Obstructions are defined as physical objects and shadows that will obstruct the collector from direct sunlight. To determine the severity of obstructions, follow the steps below.

- Stand in the desired location of your solar collector and position yourself to face true south (or in the near-true-south orientation of your solar collector).
- Make a fist extended at arms length so that the bottom of your fist is level with the top of your head.
- Rotate your fist (still extended at arms length and level with the top of your head) 45°

to the left and to the right of the true south centerline of your body.

- While rotating your fist 45° to the left and right of true south, note any obstructions that appear above your fist as it moves from side to side. Obstructions include houses, trees, tall hills, etc. Ideally, your fist will not pass through any obstructions. If more than 15% of your fist's path is blocked by obstructions, try another location for your solar collector.

While siting your batch collector on the roof might seem appealing to avoid obstructions, roof mounting requires complex installation procedures and is beyond the scope of this guide. Further, the homeowner should consult a structural engineer before proceeding with roof mounting due to the heavy weight of the filled water tank within the batch collector. For this reason, it is strongly suggested that you site your solar collector on a sturdy foundation at or near ground level.

Distance from Conventional Tanks Water Heater: The final factor to consider when siting your solar collector is the site's distance from your home's conventional water heater. The distance between the collector and the home's conventional water heater should be as short as possible. The reason for this is to minimize heat loss in the system's pipes as the water travels from the solar collector to the home's conventional water heater. You should also insulate the system's pipes with Plastic insulation such as polystyrene or polyethylene

Often the home's conventional water heater is located in the basement or on the first floor near the clothes washer and dryer. Dryers vent to the outdoors. The vent breaks the exterior wall, and is a good portal for the plumbing between your solar batch collector and the water heater inside the house. This works well when the dryer vent is located on the south-facing wall of the house.

If the vent is not on the south wall, you may have to find a different way to run the plumbing.

2. Plumbing Your Solar Batch Water Heater

The solar batch water heater described in this guide is designed to work in coordination with the homes conventional electric or gas tank water heater. Now that you have constructed and sited the batch collector, the next step is to connect the batch collector to your homes plumbing. This will involve diverting cold water flowing into your home's conventional water heater to the solar collector and then returning the solar-heated water to the home's conventional water heater tank for storage until demanded for use. In addition to rerouting of water to the solar collector, you will need to install a number of gauges, and valves to monitor performance and operate the system.

Because each system will be implanted in a unique home and location, specific plumbing installation instructions are not possible. Instead, this guide offers a list of the components you will need (though not dimensions) and a series of general steps to take to install the system.

Components List

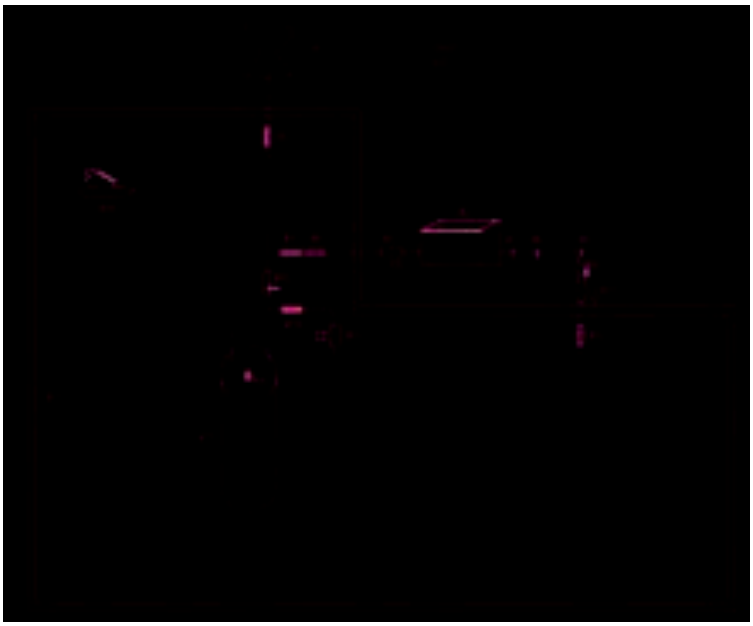
1. Copper Piping (1⁄2" inside diameter. Length varies by site.)
2. Pipe Insulation (Length varies by site.) Use heat-rated rubber insulation. DO NOT USE PLASTIC/POLYSTYRENE INSULATION.
3. 3 Isolation Valves (either Ball or Gate)
4. 2 Drain Valves
5. 1 Temperature Gauge
6. 1 Air Vent Valve
7. 7.2 check valves
8. 1 Freeze Protection Valve
9. 1 Air Vent Valve

Plumbing the System

1. Before acquiring the components, study the plumbing diagram below to understand how the plumbing works and the location of each of the components.

Plumbing Diagram

#1: Water Source
#2: Whole-house Isolation Valve
#3: Isolation Valve
#4: Check Valve
#6: Drain Valve
#7: Batch Collector
#8: Air Vent
#9: Vacuum Breaker
#10: Pressure Relief Valve
#11: Freeze Protection Valve
#12: Drain Valve
#14: Check Valve
#15: Temperature Gauge
#16: Pressure Relief Valve
#17: Conventional in-Home Tank Water Heater
#18: End-use Consumption



2. Determine the route of the plumbing into the house from outside. A good option for running the waterlines through the indoor/outdoor envelope of your home is the clothes dryer vent. Often the dryer is located near the water heater, and the vent provides an easy way to run the pipes through the wall of your house. Pipe lengths should be minimized to reduce heat loss through transmission between batch collector and conventional water heater tank.
3. Take measurements to determine the amount of copper piping needed and any pipe angles that will be necessary.

4. Acquire the necessary plumbing components. All components should be available at local hardware stores.
5. Make sure that batch collector is in the location you want. Start with two galvanized nipples protruding from the side wall of the collector box. These two should be vertically aligned. Because hot water will rise above cold water, the bottom nipple will be where the cold water enters the collector, and the top nipple will be where the hot water leaves the collector to return to the house. Run the pipes and install the proper gauges as shown in the plumbing diagram from step 1. DO NOT INSTALL ANY COMPONENTS TO THE COLD WATER LINE FEEDING THE CONVENTIONAL WATER HEATER. DO NOT CONNECT THE PIPES TO THE WATER SOURCE YET.
6. Once the plumbing lines are run, it is time to integrate the new solar system with the home's conventional plumbing. First TURN OFF THE WATER TO THE WATER HEATER. To do this, you may have to turn off the water to the entire house. From the water heater, trace the inlet water pipe back toward the source, looking for an isolation valve. If you cannot find one, find the house's Master Isolation Valve (see diagram) and move it to CLOSED. This will cut off water flow to the water heater (and perhaps the whole house).
7. With the water off, install the final isolation valve on the cold water inlet pipe to the water heater. Then integrate the cold line to the solar collector above the isolation valve. Next, integrate the hot line from the solar collector below the isolation valve. See Plumbing Diagram.

8. Now your system should be ready for use, but at the moment the new pipes have air in them. To keep the air from entering your home's plumbing system, be sure that your air vent component is functioning. Then configure the isolation valves so that #1 and #2 are OPEN, and #3 is CLOSED. Next, open the master isolation valve leading into the home or to the water heater. Fill the new pipes with water. Once full, change isolation valve #3 to OPEN and change #1 to CLOSED.
9. Monitor the system closely for the first few days to ensure the system is operating correctly. Check for leaks in the plumbing and check temperatures periodically.

Maintenance

Like all equipment, your solar water heater will require basic maintenance. Maintenance will serve two purposes. First, it will protect the system from damage, increasing the system's life. Second, it will improve the system's performance and increase the benefits realized by the system. Review the maintenance issues listed below.

1) **Freeze Protection.** Some degree of freeze protection is necessary in all climates except tropical. In climates with moderate or high freeze risks, two options are available.
    - *Freeze Protection Valves* will prevent freezing in the systems outdoor pipes and batch collector. These valves work by continuously bleeding water from the system just before the warm water return pipe (from the batch collector) enters the house. Freeze protection valves work automatically once installed, but because freeze protection valves function by continuously bleeding water through the system, their recommended use is in conjunction with drainage systems in locations that see

frequent and/or severe cold temperatures.

Procedure: 1) Maintain freeze protection valve. To do this, 2) check the valve regularly for mineral deposits that may cause the valve to fail. See maintenance issue #2 below for details on checking the valve.

Draining the System is the best way to prevent freezing. The system should be drained with severe cold temperate or multiple days of near freezing temperatures. In cold climates, it is recommended that the system be drained and inactive for the coldest months of winter, usually December-February, even if freeze protection valves are installed. In addition to draining the system, the plumbing valves must be configured for the traditional

Procedure: To drain the system: 1) Close the isolation valve located on the cold water line leading to the collector. 2) Close the isolation valve located on the hot water line from the collector to the indoors conventional hot water heater. 3) Open the isolation valve from the local water source leading into the conventional indoor hot water heater. 4) Open the drain valves located at the lowest points of the outdoor piping. When you are ready to use the system again after winter, remember to open the two isolation valves on the solar lines (hot and cold) and close the isolation valve on the cold waterline from the local water source into the conventional heater. This is necessary for the water to be diverted through the solar collector before entering the conventional water heater tank.

2) **Maintain Plumbing.** Minerals dissolved in water will deposit themselves throughout any plumbing system. These deposits are particularly bad in places with hard water or water high in mineral content.

Procedure: Once a year, 1) check the anode rod in your solar collector's water tank, and 2) check for mineral build up in the system's plumbing by removing valves and checking for mineral build up. To do this, 3) drain the system according to the drainage procedure under Freeze Protection. Then remove valves and anode rod. 4) Clean valves and replace rod when necessary. Because the system should be drained to perform this procedure, it is recommended to perform this procedure when the system is drained for the winter each year.

3) **Thermal Integrity of the Batch Collector.** The suns rays deposit a large amount of heat energy in the things they contact. This heat then dissipates mainly by convection and radiation. The batch collector box should minimize this dissipation. The two important factors are air tightness and insulation.

Procedure: 1) Maintain air tightness and insulation. 2) To maintain air tightness, check and maintain air seals at all joints of the collector box. 3) To maintain insulation, make sure insulation stays in good condition inside the collector box and find a thermal barrier to cover the glazed top of your collector at night. One suggestion is a hot tub cover that folds in half. One half of the cover will cover the glazing with the other half of the cover resting against the back of the collector. Cover the glazing each night. While this suggestion will increase your systems performance, it is not necessary for you to realize benefits of your system.

4) **Behavioral Suggestions.** In addition to the three maintenance issues described above, another important factor in the performance level of your system will be the behavior of household's occupants. Some simple steps on your part can drastically increase the performance and benefits of your solar water system. While these steps will improve your system's performance, they are only suggestions and are not required maintenance.

Procedures: 1) Cover the Glazed Top of Your Collector at Night. Your collector will radiate large amounts of heat to the glazing on the top of the collector. The glazing will transmit the heat outside the collector box, and the heat stored up over the day will be lost. A way to counter this heat loss is to cover the glazed top of your collector with a good thermal barrier each night after the sun goes down. 2) Shower, Do Laundry and Dishes in the evening or at night. At the end of each day, your solar water heater has absorbed a days worth of solar-thermal energy. This is the optimal time to use hot water because the system will not have lost much heat back to the cooling nighttime conditions.