



## A SOLAR WATER HEATER BY YOURSELF

### CONSTRUCTION MANUAL AND WORKING PRINCIPLES OF A SOLAR WATER HEATER BY THERMOSIPHON\*\*



Manual version 1.2, English

\*French international solidarity association

**\*\*For tropical countries, cannot be used if the temperature may go below 0°C**

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# **INTRODUCTION**

The main purpose of the association *Développement Futé et Raisonné* is to collaborate with needful population by sharing its knowledge with the intention of increasing their living conditions, in particular for the children. The main fields of the organization are: education, health and construction in an aim of a smart and sustainable development accessible to everybody.

The aim of the present manual is to make anyone able to construct by himself a domestic solar water heater. It takes place in a project that has got the willingness of giving to everyone the possibility to access to some essential facilities and technologies by using themselves simple materials and techniques.

There are many types of solar water heaters, with different materials, prices, advantages and disadvantages but we will only present one of these in this manual. However, to be the most exhaustive possible we will also present in the end some other materials and different ways to do the construction of a solar water heater (chapter V/ *Different solutions and materials*).

This manual can be copied, distributed and used freely and cannot be sold by anyone. Its content is anyway under the copyright of *Développement Futé et Raisonné* (DFR).

DFR declines any responsibility from whatever could occur while constructing or using a solar water heater and does not give any warranty on this product.

We invite anyone who would like to help this project to do so. It can be by giving new ideas, by sharing experiences, or simply by giving us a feedback about this manual.

If you made a solar water heater with the help of this manual (even in parts) PLEASE send us some pictures of it on our E-mail address.

*DFR team.*

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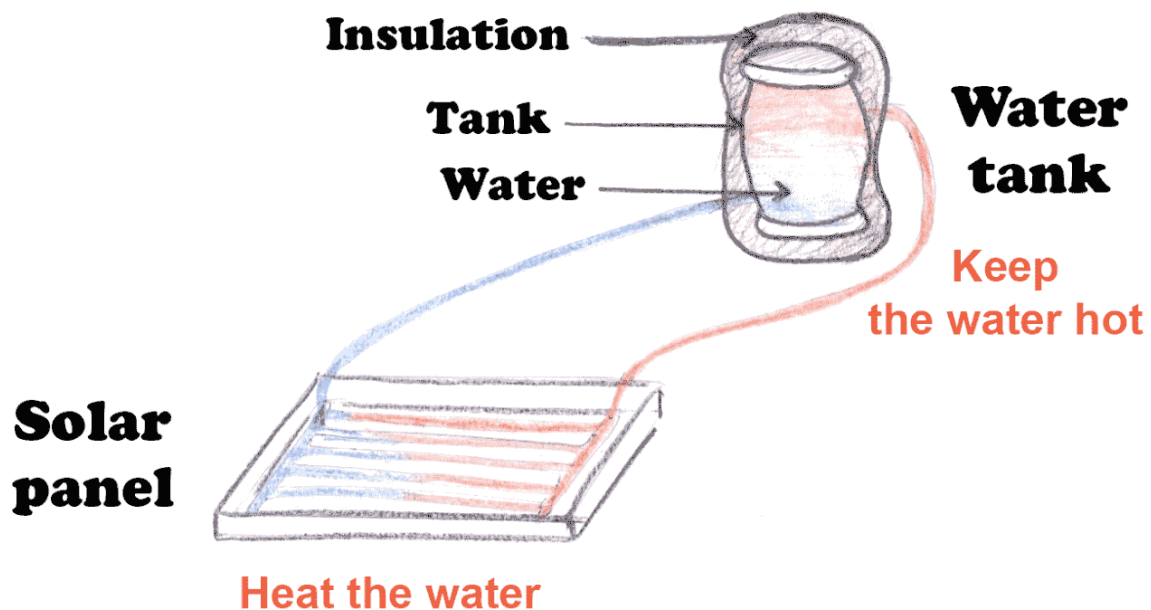
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# I/ SOLAR WATER HEATER WITH THERMOSIPHON

## 1) Solar Water Heater, working principles

A solar water heater is made of two different parts: **the solar panel**, which is using the energy of the sun to heat the water, and **the hot water tank**, which contains the water and keep its heat inside.



## 2) The solar panel

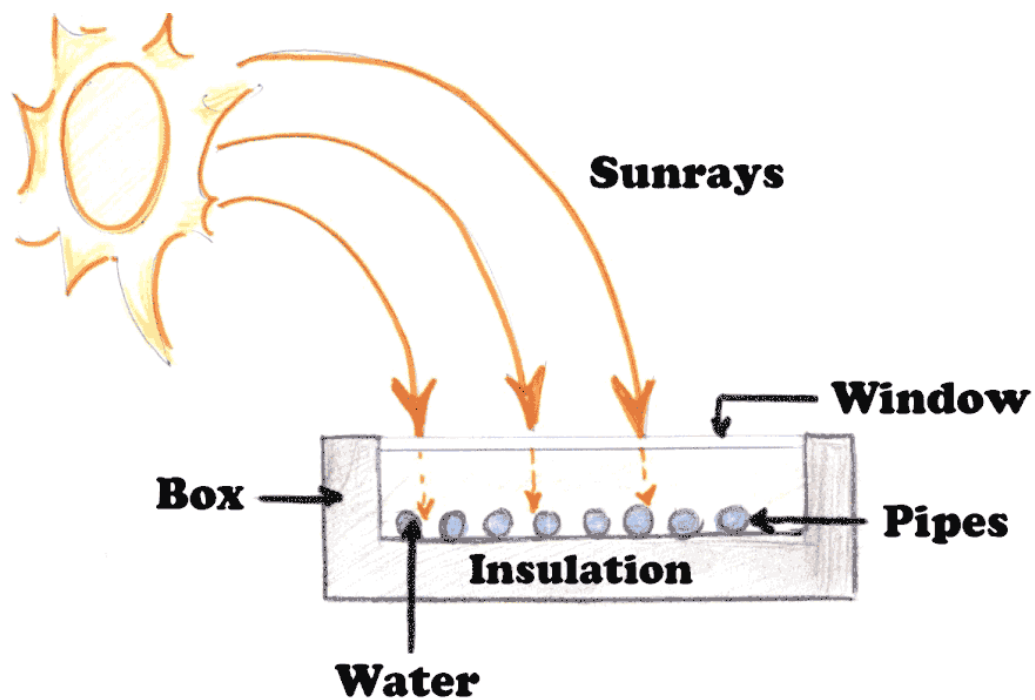
A solar panel is a box with a window over it and some water (or another fluid) circulating inside. The sunrays passing through the window are heating this water. In our case, we will use metal pipes inside the panel to make the water circulate.

To increase the solar panel efficiency, it is necessary to do several things.

First we paint the pipes in black color to absorb a maximum of energy from the sunrays.

Then we set a metal sheet under the pipes, and we paint it in black. This sheet will also absorb some energy and give it to the pipes by conduction (contact). It will also heat the air inside the panel by convection.

Finally, because the box is hermetically closed, it is creating a greenhouse effect. This will heat the air trapped inside the panel. To increase this phenomenon, we will insulate the solar panel. By this way we can limit the loss of heat inside it.



Therefore, the water is going to heat because of three factors:

- By direct radiation because of the sunrays passing through the window.
- By conduction because of the metal sheet which is giving its heat to the pipes.
- By convection because of the greenhouse effect created by the window and the hermetic box. Indeed, the air inside the panel will increase in temperature and heat the pipes.

### **3) The hot water tank**

The hot water tank is simply a container with thermal insulation around it. The size of the water tank and the quantity of hot water depends on the size and the efficiency of the solar panel. If you want to use a bigger tank to heat more water, you will need a bigger solar panel, or several panels connected together.

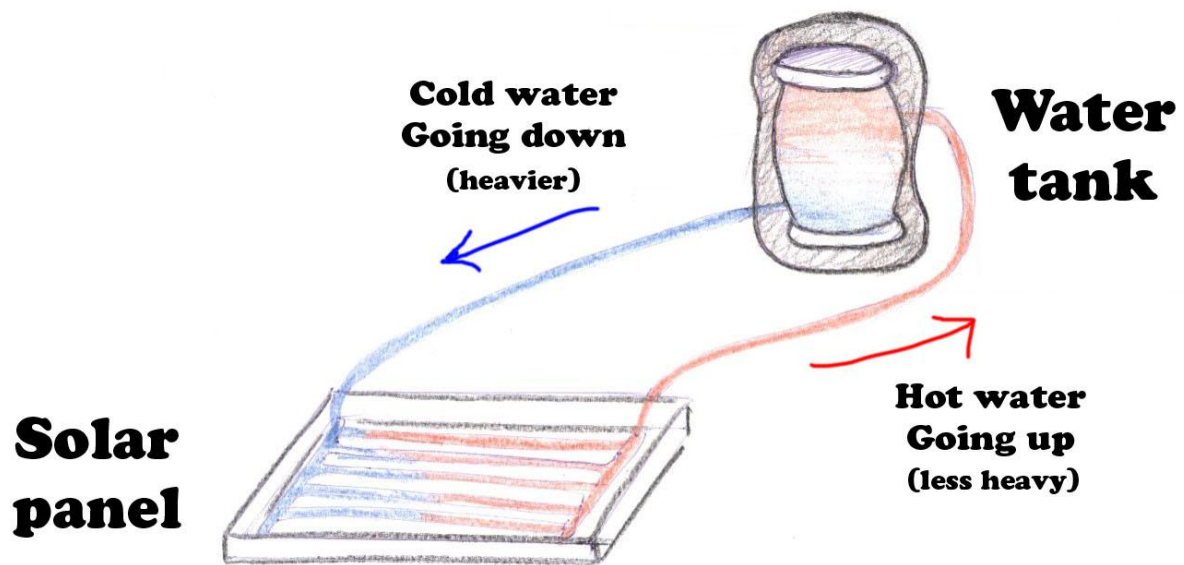
So, the most important part of a hot water tank is its insulation. Its aim is to limit the heat losses. By this way, the solar water heater efficiency is increased in the day and it is possible to keep the water hot during the night.

### **4) Water circulation principle: the thermosiphon**

A solar panel must heat the water that is inside the tank. To make this possible you have to create a circulation of the water between the panel and the tank. One possibility could be to install a water pump (a motor) on the system, but this needs some electricity (which can be a big problem in many parts of the world). However, the nature is well made and has provided us the quite interesting *thermosiphon* phenomenon.

To explain it a bit theoretically, the water expands itself while heating (its volume increases). That means if you fill two identical bottles, one with water at 20°C and the other one at 80°C, the first one will be heavier. It is this phenomenon that we will use to make the water circulating in our solar water heater.

Now imagine that the hot water tank is connected to the solar panel and placed **above** it. The sun will heat the water inside the panel so this water will become lighter and will go up in the water tank. And the water in the bottom of the tank, which is the coldest and so the heaviest, will go down in the panel and start to be heated. This creates a circulation that allows the solar panel to heat all the water inside the water tank.



## **CIRCULATION BY THERMOSIPHON**

## **II/ MATERIALS AND TOOLS REQUIRED**

### **1) Information**

The solar water heater that will be presented here has been developed specially for Nepal. So the materials used in its constructions will be easy to find almost everywhere in Asia. For others parts of the world, some changes will certainly have to be done. This system has also been developed for tropical countries and **cannot be installed if the temperature may be below 0°C** (problems of frost).

All the dimensions given in this manual are only for indication and can be changed. Nevertheless, they have been chosen on one hand for the optimization of the materials and on the other hand to make the dimensioning easier. Indeed, one panel is developed to heat 100L of water. Then, each solar panel can be connected with another one to increase the amount of water to heat. For example, if you want to heat 300L you will have to connect three panels together.

In every step of the construction, you will be informed that **you can use different materials from the ones presented here**. If you want to know more about the alternative materials you can use, please refer each time to chapter V/ *Different solutions and materials*.

**If you have any doubts the picture of some materials and tools can be found in Annex.**

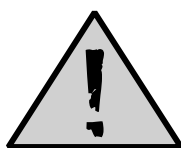
### **2) Materials**

Prices and materials for a Solar Water Heater (100 to 150 liters; 1 panel; 1,7 square meters) in NEPAL (Sauraha, Chitwan)			
Materials	Quantity	Unity price (Rs*)	Price (Rs)
<b>Pipes</b>			
GI pipes 1/2inch * 6m (good quality)	3	785	2355
GI pipes 1inch * 1m (good quality)	2	300	600
Hole making and Welding	1	1000	1000
		Total pipes:	<b>3955</b>
<b>Panels</b>			
Zinc sheet (thickness 0,3mm or more) 4*8 feet	1	750	750
Aluminum sheet (0,1mm or more) 4*8 feet	1	550	550
Glass window 89*107cm thickness min. 5mm	2	600	1200

Plywood sheet 3*7 feet (thinnest)	1	220	220
Plastic sheet opaque 1m*2,5m	2	150	300
		Total panels:	<b>3020</b>
<b>Insulation</b>			
	(Meters)	(per meter)	
Plastic foam thickness 12mm ***	12	150	1800
Plastic foam thickness 8mm ***	3	110	330
*** (comes by big rolls of 1,4m high)			
		Total insulation:	<b>2130</b>
<b>Water tank</b>			
Thick plastic tank for chemicals (100 to 150 liters)	1	1000	1000
Second hand metal sheets for the tank box	1	500	500
Garden pipe 1/2inch * 2m	1	100	100
Tank Nipple 1inch	2	180	360
Tank Nipple 3/4inch	1	140	140
Tank nipple 1/2inch	1	90	90
Toilet valve system 1/2inch	1	180	180
		Total water tank:	<b>2370</b>
<b>Connections:</b>			
PEHD pipes 1inch * 5m	1	250	250
GI Elbow 1inch	6	80	480
GI Socket 1inch	4	70	280
GI Nipple 1inch * 3inch	2	45	90
GI Nipple 1inch * 2inch	4	35	140
GI Male cap 1inch (to close pipe)	2	30	60
GI Union 1inch	4	115	460
GI Nipple 3/4inch * 3inch	1	35	35
GI Nipple 3/4inch * 2inch	3	25	75
GI Nipple 3/4inch * 9inch	2	140	280
GI Union 3/4inch	1	100	100
GI Elbow 3/4inch	1	60	60
GI Socket 3/4inch	1	50	50
GI Male cap 3/4inch (to close pipe)	1	20	20
GI Tee 3/4 inch	1	80	80
Ball Valve 3/4inch	1	200	200
Non-Return Valve 3/4inch	1	250	250
GI Nipple 1/2inch * 3inch	2	30	60
GI Nipple 1/2inch * 2inch	2	25	50
GI Union 1/2inch	1	80	80
GI Elbow 1/2inch	1	50	50
GI Socket 1/2inch	3	40	120
GI Male cap 1/2inch (to close pipe)	1	10	10
Ball Valve 1/2inch	1	10	10

		Total connections:	<b>3290</b>
<b>Others :</b>			
Glass sealant (silicone <b>clear</b> ) tube 200ml	2	180	360
Black board paint 0,5L	1	100	100
Aluminum foil (for cooking) (*9m)	3	75	225
Grinding paper (1 square foot more or less)	1	20	20
Turpentine oil 0,5L (to wash paint)	1	60	60
Sachet of small rivets (repeat)	1	40	40
Electric scotch tape	10	6	60
Plastic string 20m	1	50	50
Iron wire 0,5kg	1	50	50
Threading tape (PTFE, Teflon)	10	10	100
Wood glue (Fevicol) 125mL	1	50	50
Round metal fixer	2	10	20
One dozen of nails of several sizes	1	20	20
Epoxy putting (in case of leaking)	1	45	45
		Total others:	<b>1200</b>
		<b>TOTAL</b>	<b>15965</b>
<b>Standing Iron Structure</b>			
Iron + welding to hold one panel	1	700	700
Iron + welding to hold the water tank	1	1400	1400
Metal primer 200mL	1	110	110
		Total structures:	<b>2210</b>

\*Rs: Nepalese Rupees. 1Rs = 0,01€ more or less in 2010



## ALWAYS TRY TO RECYCLE!

A lot of these materials can be found in ‘second hand’ (wood, metal sheets, pipes, insulation...). By recycling the maximum of materials it is possible to decrease **considerably** the cost of your solar water heater. Some examples are given in the end of this manual in chapter V/ *Different solutions and materials*. The estimated price of a solar water heater realized with a maximum of recuperation materials is also given in Annex.

### **3) Tools**

#### **Tools required or useful**

Sharp knife  
Paper cutter  
Rubbing paper  
Big Hammer (2 pieces)  
Pipe wrench (2 pieces)  
Metal saw  
Paint brush  
Pliers  
Metal scissors  
A piece of GI pipe ½ inch  
Board pen  
Pieces of wood of several sizes  
Measuring tape  
Silicon pistol\*  
Riveting-machine (repeat gun)\*  
Hand or electric drill\*  
Thermometer\*  
Threading machine\*  
Metal square (right angle)\*  
Welding machine\*  
Drilling machine\*  
Vice\*  
Spanner\*

\* Not compulsory

### **III/ EXPLANATIONS AND CONSTRUCTION TIPS**

#### **1) Preparation and location**

First of all, we advise you to read entirely this manual, at least in its great lines, before starting the construction or buying any materials.

You also must choose the capacity of your future solar water heater to know the materials you have to buy or find. If you want more than one solar panel (so more than 100 or 150 liters of hot water), please refer to chapter *V/ Different solutions and materials*. To have more idea about the usual water consumption we give you this table.

#### **Estimates requirements of hot water per application**

<b>Application</b>	<b>Typical Requirement of Hot Water at 60°C.</b>
Household bathing using buckets	10-20 liters per person per bath
Household bathing using shower with a mixing tap	15-30 liters for 5-10 minute shower
Shaving, while a tap runs	5-10 liters
Household bathing in bathtub (one filling, depends on size)	75 - 100 liters
Wash basin with a mixing tap (hand wash, brushing of teeth, etc.)	1-5 liters per person per day
Kitchen washing	10-20 liters per washing
Dishwasher	40-50 liters per wash cycle
Clothes washing machine	40-50 liters per wash cycle

Note: All the estimates are given for hot water at 60°C. This hot water has to be mixed with cold water to bring down its temperature to endurance limits. Mixing will also increase quantity to actually required values. You can decrease these amounts by using carefully your hot water.

Then, you must find the place where will be installed your solar water heater.

There are major things that have to be considered to choose this location, in order of importance:

- The security: you don't want your solar panels to be damaged by any animals, falling branches etc. It should also be out of reach of children.
- The sunlight availability: a good place will have full sun 8 hours per day.
- The location of the hot water outlet. The distance between the solar water heater and the hot water outlet (shower for example) has to be the shortest possible to minimize

the heat losses.

-The location of the cold water supply. If you minimize the distance between it and the solar water heater you will decrease the price of the connection pipes.

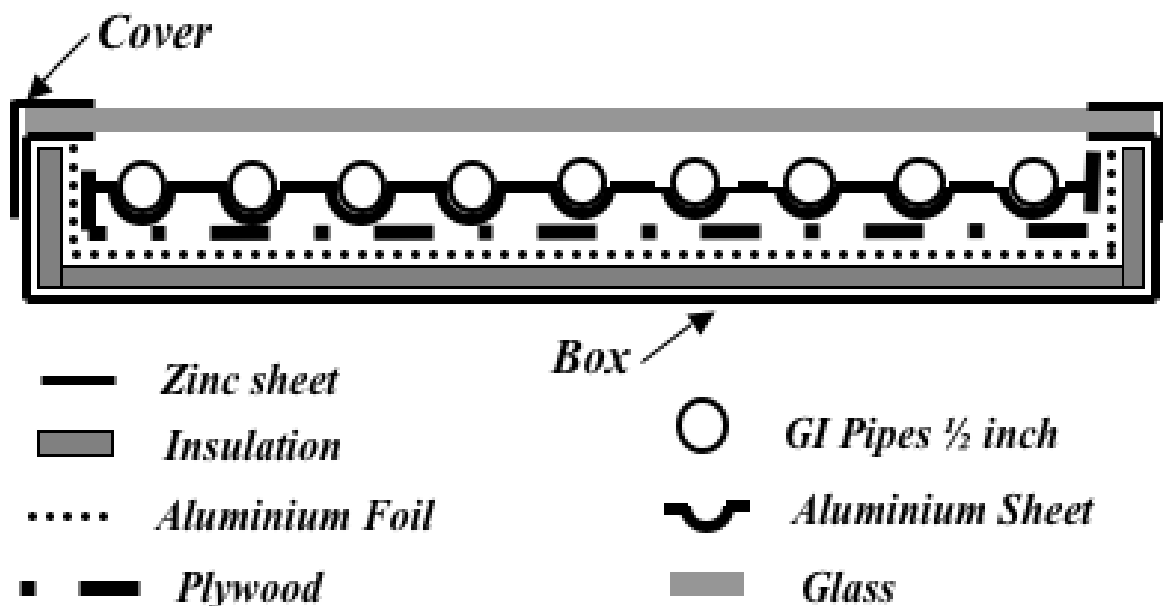
You should also consider that the tank needs to be high enough to have a sufficient pressure of water. So it is better to have your solar water heater at least one floor over the showers.

We also advise you to make the welding of the pipes and eventually of the standing structures before starting the construction, because it could take some time. Please refer to *III/2)c/ The pipe system* and *III/4)a/ Standing structures, inclination*).

You can also choose a place where you can find a way to hold your panel(s) or/and hot water tank without constructing any standing structure; this will considerably decrease the price of your installation.

## 2) Construction of the solar panel

### **a/ Global pattern**



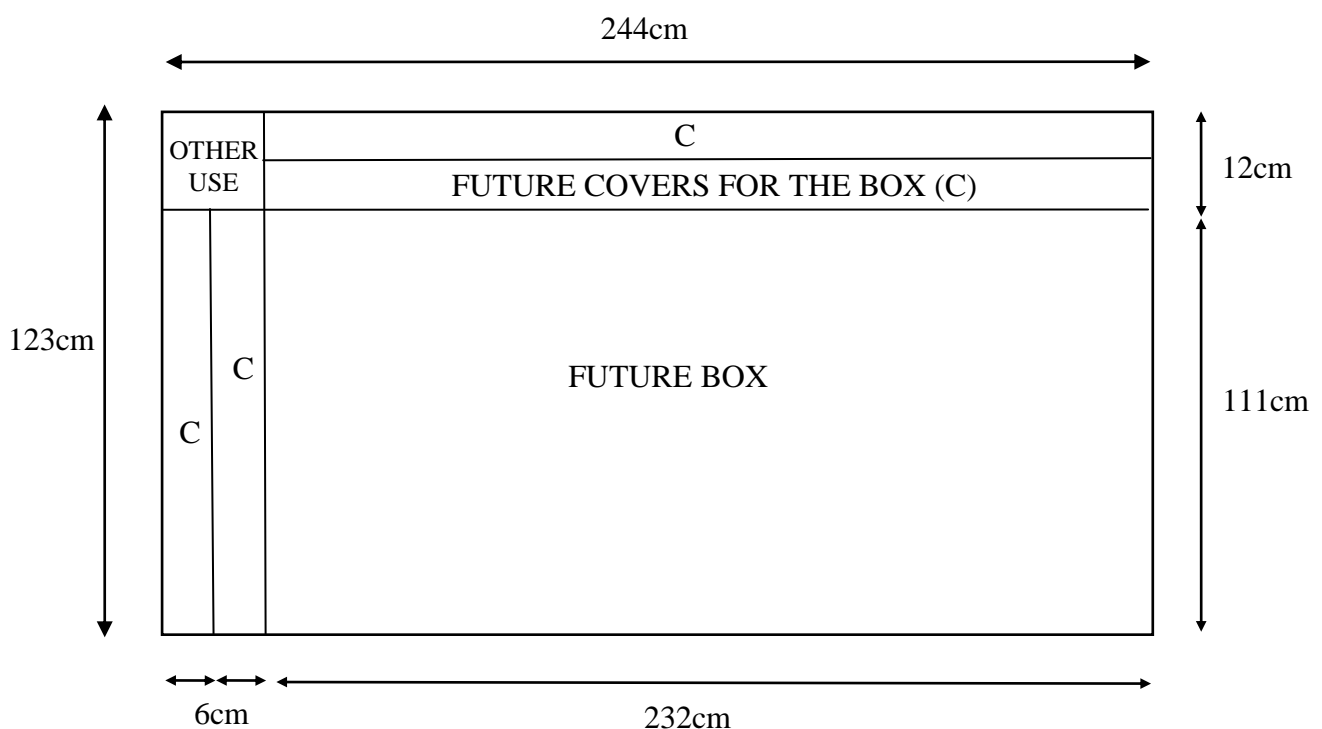
## b/ Construction of the box

### **Tools and materials:**

- Two hammers (or a riveting-machine)
- Few pieces of wood
- Metal scissors
- Board pen
- Measuring tape
- Right angle (not compulsory)
- Small rivets
- Few nails

To make the box in which will be placed the pipe system, you could use many different materials, as will be explain in the end of the manual (*V/Different solution and materials*). In this example, we will use a zinc sheet (length: 8feet, width: 4feet, thickness 0,3mm). It has the advantages to be light, stainless and easy to work on.

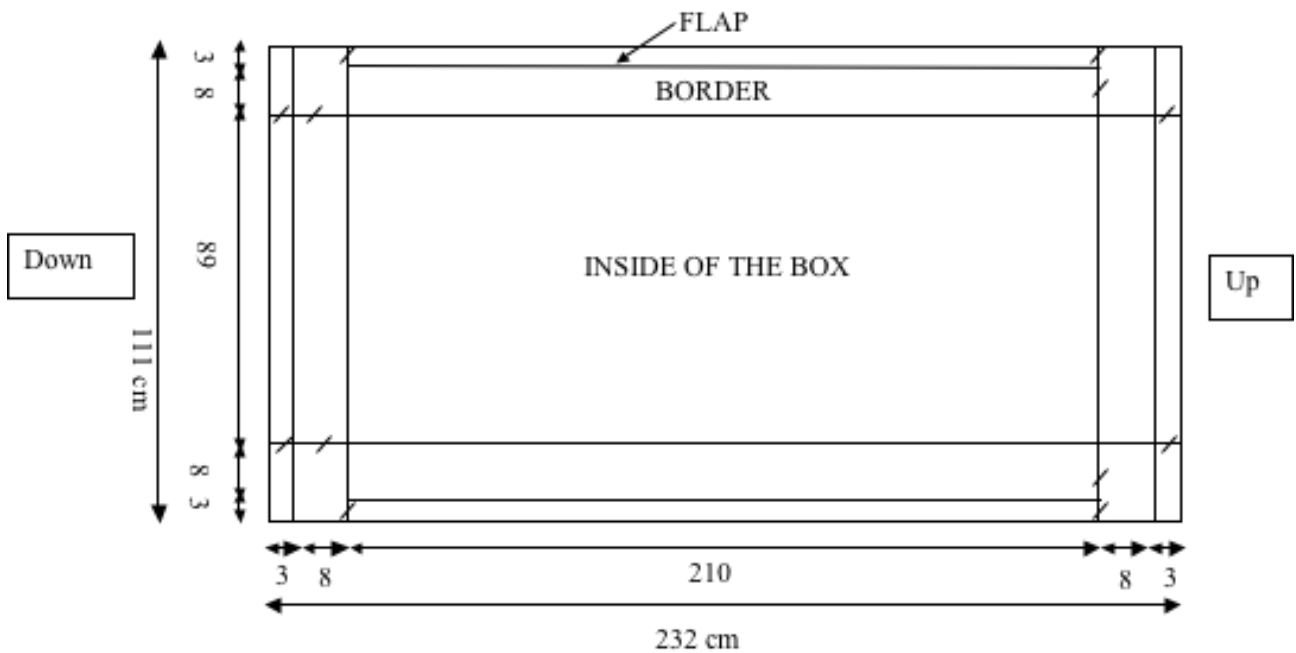
The zinc sheet will be used for several parts of the panel, that's why the first thing you should do is to cut it as below:



Now you can take the 'future box' and keep the others pieces somewhere else. You are going to fold this zinc sheet to give it the form of a box.

The outside dimensions of our future box are: length: 210cm, width: 89cm, height: 8cm and a flap to place the window: 3cm.

You can start by drawing this matrix on your previously cut zinc sheet:

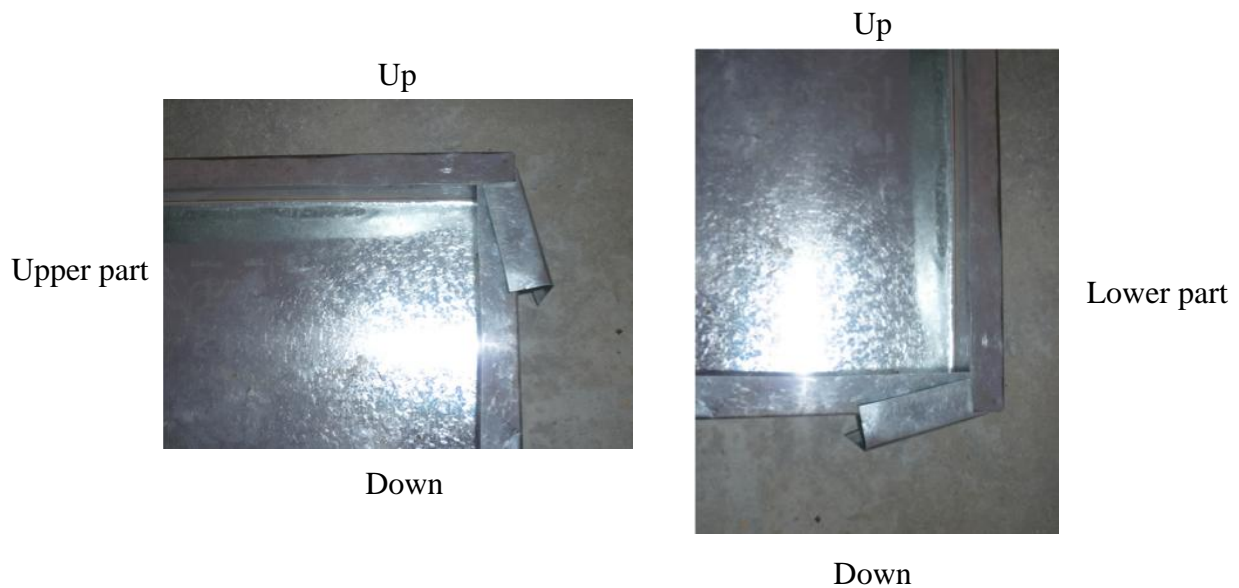


Then you only have to cut on the crossed lines and to bend the zinc on the straight lines. You can use a straight piece of wood to make the folding.

It is easier to start to bend the widths of the sheet (smallest sides) and to do the borderlines first (the 3cm flaps to put the windows over). And then you can do the lengths, but still starting by the flaps.

**Be careful:** the folding will be different for the upper part and the lower part of the box, as explained in the following.



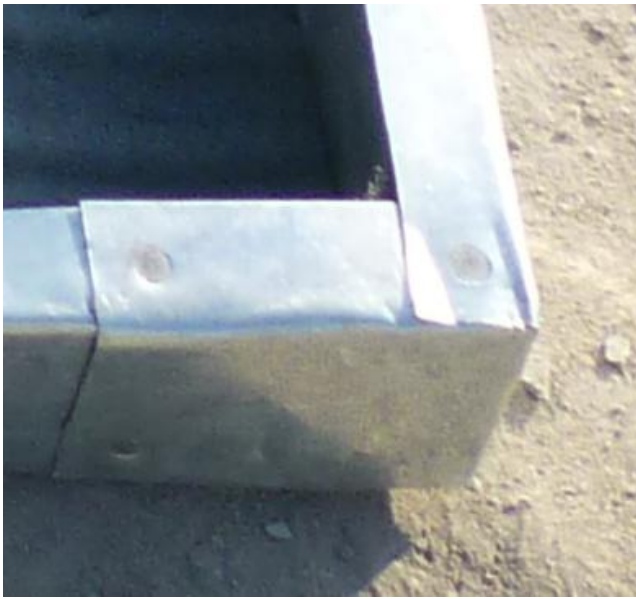


This is a little zoom on the upper and lower sides of the box. Their different forms are made to prevent water infiltration inside the box (look how they cover each others).

Once the box is ready, you have to place the rivets. So you should first make a hole in the sheet with a nail of the size of your rivet (you should place a piece of wood under the zinc to prevent from deformation). If you don't have a riveting-machine (repeat gun), you can use two hammers (and a piece of wood to adjust the height) to fix the rivets, as on the picture below.



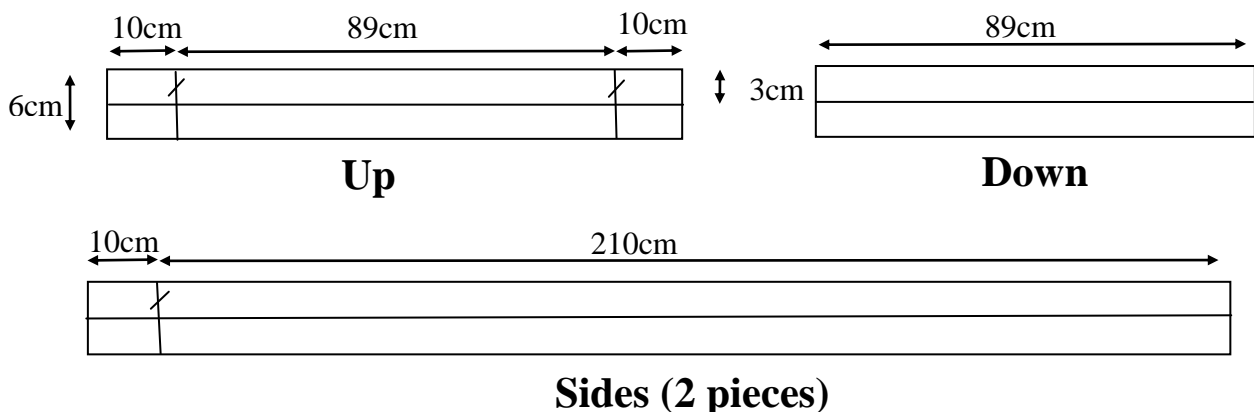
Your box should look like this when finished:



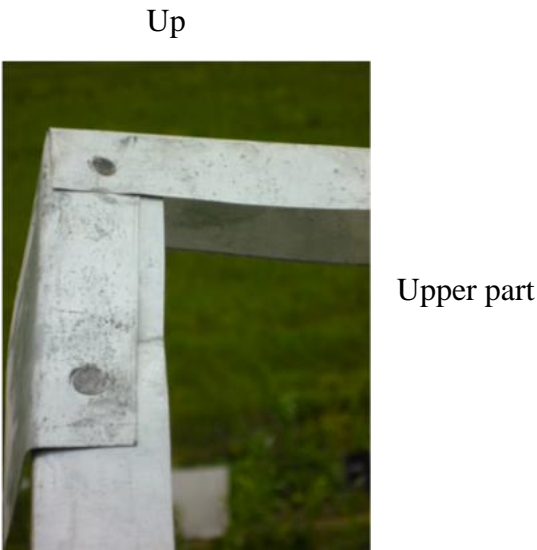
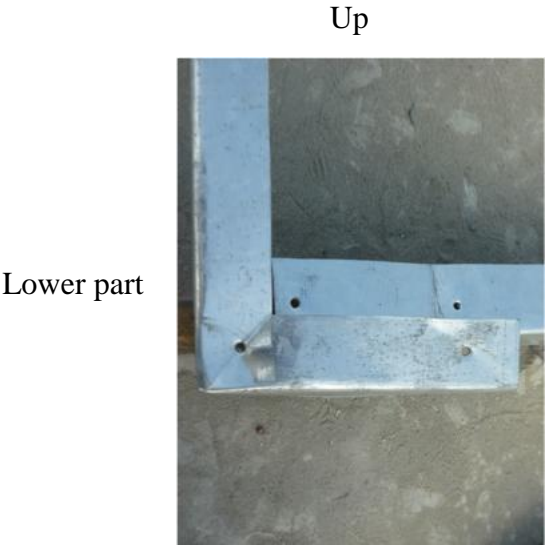
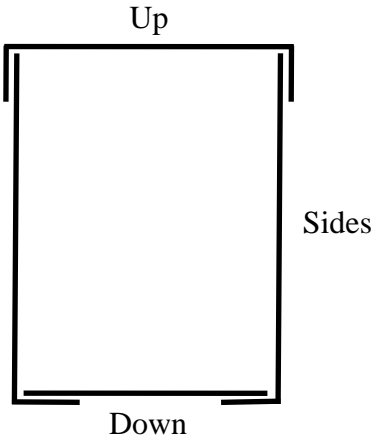
The glass windows will be fixed with some silicon glue on the flaps of this box. That's why we are going to add some little covers over it to protect the silicone and help to prevent any water infiltration.

These covers will be 3cm over the windows and on the sides, so they have a total width of 6cm. And if you have cut the zinc sheet as explained before you already have some long pieces of zinc of 6cm width so you only have to cut them at the right size.

The top one should be 109cm long (89cm of the box width and 10cm more on each side to place the rivets). The two sides ones 220cm long (210 length of the box and 10cm more to place the rivets on the last piece). The last one, which will be down, will be simply the width of the box: 89cm.



Then you only have to fold on straight lines and to cut on the crossed lines; and then to rivet everything together as below. We advise to make it 0,5cm longer everywhere to be sure it will fit around the panel.



## c/ Insulation

### **Tools and materials:**

- Blade or knife
- Metal saw
- Measuring tape
- Metal pliers
- Board pen
- Paint brush (after use don't forget to wash with turpentine oil, then soap and water)
- Sticking tape
- Plastic foam 12mm thickness (4 meters)
- Aluminium foil (9 meters)
- Plywood sheet 3\*7 feet (thinnest)
- Black board paint 0,5L

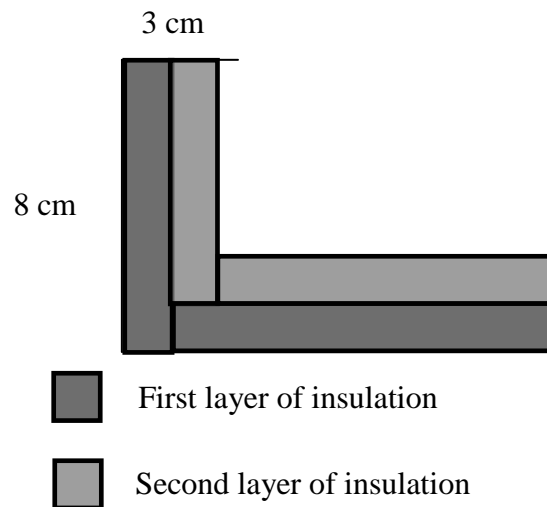
Now the box is ready, the next step is to insulate it. We will use some polyethylene foam (thickness 12mm), easy to find in Nepal. As always, we could use many different materials (and more ecologic) to make this insulation. To know more about it please refer to chapter *V/ Different solutions and materials*.

We will make two layers (24mm of insulation); you can put three layers if you want to increase the insulation. Actually you can put even more if the temperature where you leave can be low (**but never under 0°C with this kind of solar water heater!**).

You have to place the foam on the borders and then on the bottom of the box. It is better to make the four sides of the border with a single piece of foam, as below.



This is for the first layer. For the second one, you should place the pieces of foam so that they cover each other (so always starting by the borders) as below:



Then you may cover this insulation (bottom and borders) with some alimentary aluminum paper (it helps to keep the heat by sending back a part of the infrared rays emitted by any hot corpse). One side of the paper is brighter; you have to put it on the top.



You can use some little pieces of sticking tape to fix it.

Now, you need to place some plywood to protect all the insulation.



So, cut the board with a sharp knife (or a saw) at the good dimensions to fit exactly on your insulation. You can use some wood glue to fix the pieces on the borders. Then you can put some weights to hold everything while the glue is drying.



Your box is almost finished; you have now to make the four holes on the sides of the box in which the pipes will pass through. They have to be at the right place so you can easily put your pipe system inside. If you want to connect two or more panels together, please be careful that the holes are exactly at the same height on each panel otherwise they will be difficult to connect.

In **one side** of the panel, you will have to cut the zinc that is over the holes (as below) otherwise you won't be able to enter the pipes. You can use a sharp knife and a hammer to make the round holes and a metal saw to cut over it.



## **d/ The pipe system**

### ***Tools and materials:***

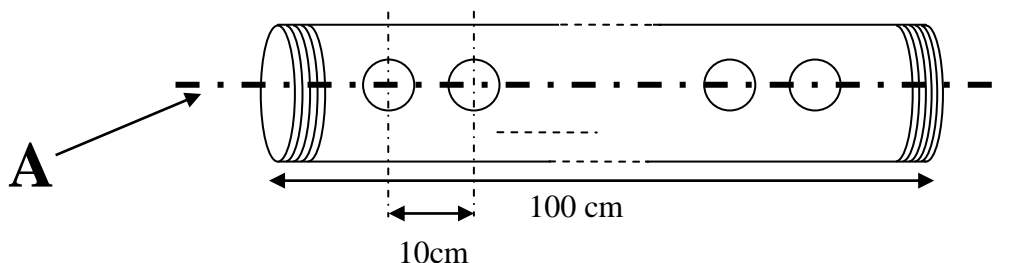
- Welding machine and bars, metal saw, drilling machine, vice, threading machine (not compulsory)
- Hammer
- Measuring tape
- Metal pliers
- Board pen
- Few pieces of wood
- Pliers
- Iron wire
- Aluminum sheet (0,1mm or thicker) 4\*8 feet
- Two GI pipes 1/2inch \* 6m (good quality)
- Three GI pipes 1inch \* 1m (good quality)

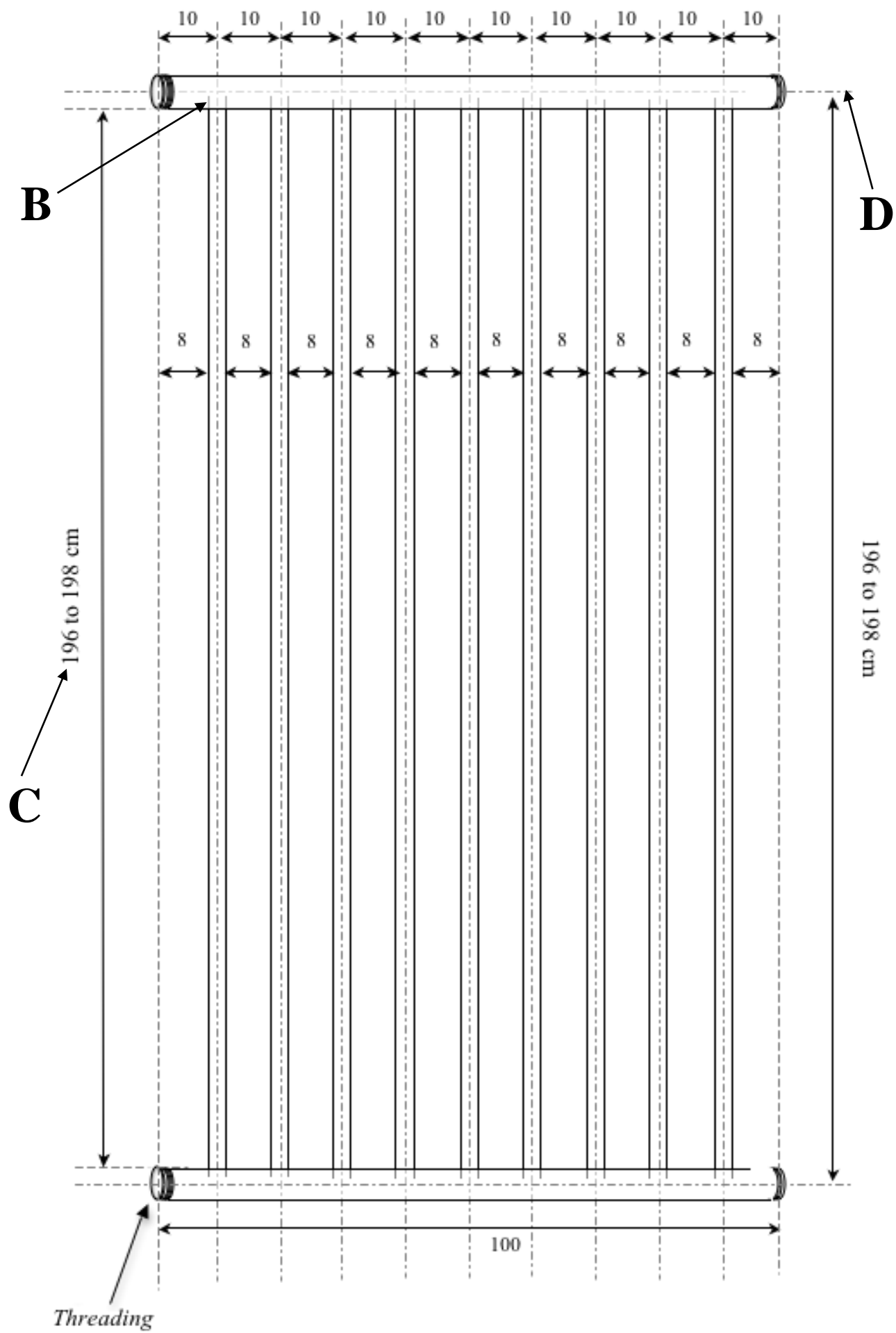
To make the circulation of the water possible inside the panel, we will make a pipe system. In this example, we will use iron (GI) pipes and weld them together. If you are not an experienced welder, we advise you to make it done by a professional.

The sizes have been chosen to use 6 meters pipes (the usual dimensions). You just have to cut the threading on the end (if there is one) and to cut the pipes in three pieces. You need nine pipes with **exactly the same dimension**.

We are giving plans below to make the construction easier but you should first know some important points that has to be followed to have a good pipe network:

- ⇒ **Always fill your pipe system with water (you have to close two inlets) to check if there is no leaking before taking it back from the welding place.**
- ⇒ The holes have to be **on the same line** on the two 1 inch pipes. *Letter A on the patterns.*
- ⇒ The 1/2inch pipes have to go a bit inside the 1inch pipes to make it strong, but not too much because it could partly break the thermosiphon circulation, (between 0,5 and 1cm inside should be good). *Letter B on the patterns.*
- ⇒ Be careful to have a good parallelism. The pipes must have exactly the same size and the distance between each other must be same.
- ⇒ If you want to connect two or more panels together, the two big horizontal pipes have to be exactly at the same distance from each other. Otherwise you won't be able to connect them together. *Letter C on the patterns.*
- ⇒ These horizontal pipes should also be perfectly straight. *Letter D on the pattern.*

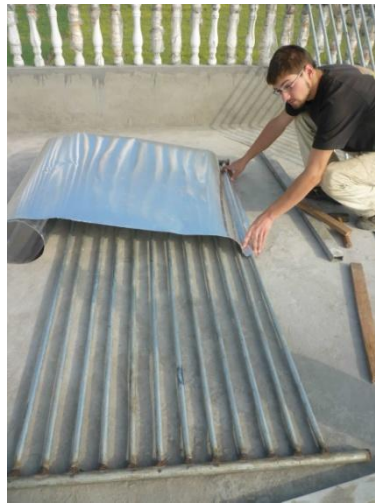




Now, to increase the surface that will receive the sunrays we will use an aluminum sheet, which is an excellent thermal conductor and will give its energy to our pipes. But to have a better efficiency, you have to give the form of your pipe system to the aluminum to increase the contact surface between each other. So, the tricky part is to bend this sheet to give it perfectly the good shape, and this is not so easy.

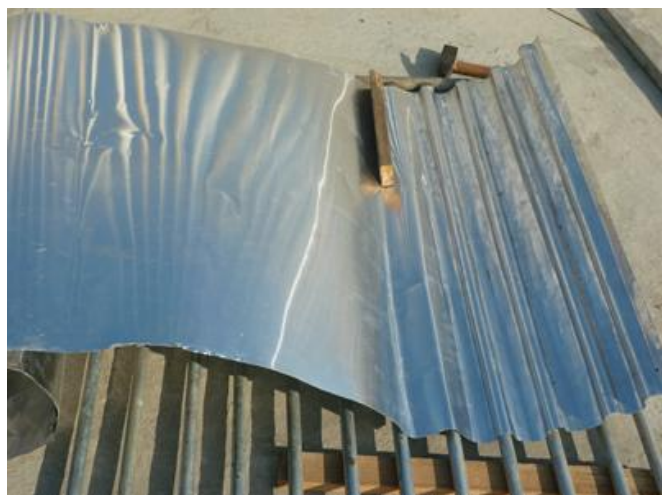
That's why we will bend the sheet directly on the pipe system.

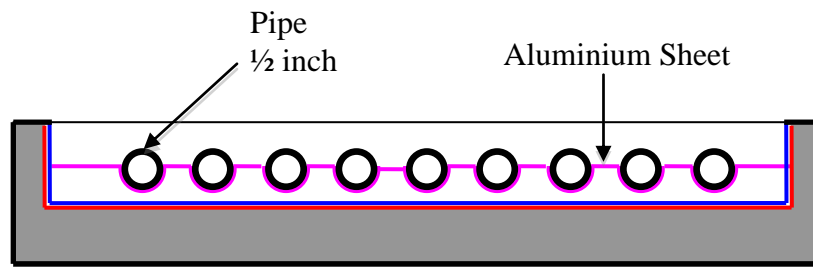
Place the aluminum sheet perpendicularly to the pipe system, as on the picture below (because it is easier to make it in two steps than in one).



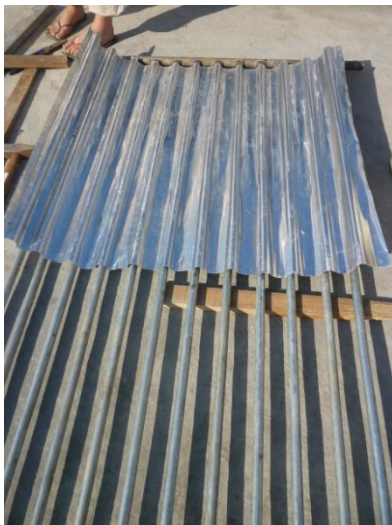
You may let the sheet exceed a little at the two borders of your pipe system (one or two centimeters) but it should not exceed 84 cm width in total to enter inside the box.

Find or cut a long piece of wood and push it very firmly between the two first pipes (you can help yourself with a hammer). Continue the same operation for the other pipes, **but be careful that each time the last bending didn't move!** This operation is not easy and can take some time to do but it is very important for the efficiency of your panel. So stay calm, take your time and try to do it well.



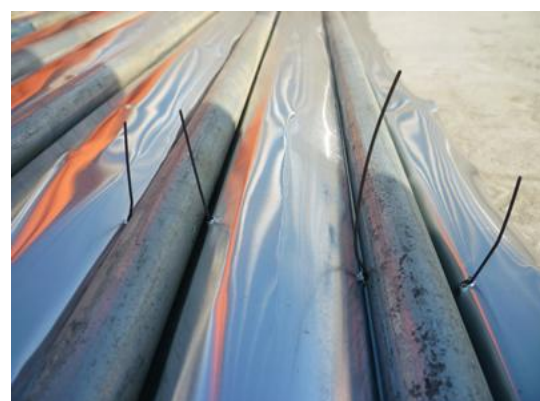
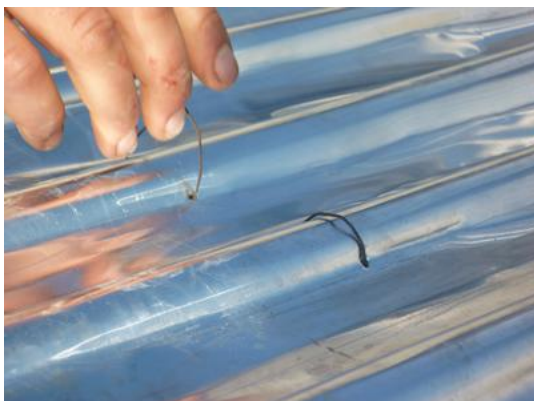


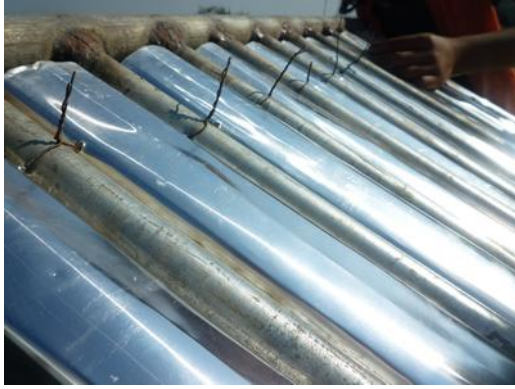
When you have finished the first half, cut the sheet near the border. Then start all over again to cover the second half of the pipe system. You may let the sheets overflow 10 centimeters on each other.



To achieve this part of the construction, you need to fix the sheet on the pipes with some iron wire to have the best contact possible. To do this, make little holes on the sides of the pipes with a nail and pass the wire through them as below.

Then tighten them by turning them with a pair of pliers until the contact is good between the pipes and the aluminum sheet. You want to put at least 5 to 10 pieces of wire on each pipe to have a good contact.





Finally, you only have to place correctly the pipes inside the box and then to take a brush and paint everything with your black board paint.



## e/ Windows

### **Tools and materials:**

- Silicon pistol (otherwise you can use the backside of a hammer to push the silicone out)
- Measuring tape
- Metal pliers
- Rubbing paper
- Weights (bricks for example)
- Silicone glue (2 \* 200ml)
- Two Glass windows 89\*107cm thickness min. 5mm
- A little piece of zinc sheet
- Pieces of unused plywood

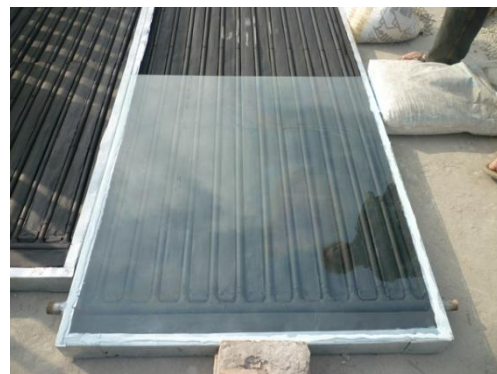
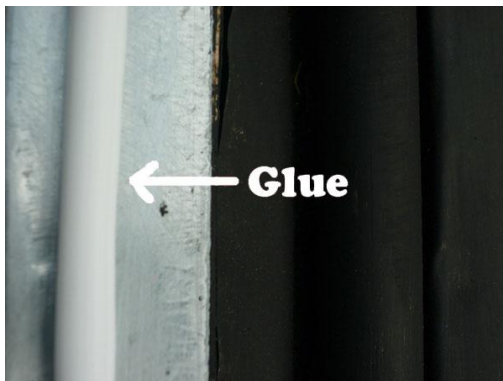
Before beginning anything, you should put your panel in a dry and covered place because any infiltration of water while the silicon glue is drying could be bad.

The first thing to do is to clean the flaps and to rub them well with some rubbing paper (to increase the strength of the sealing).

Then, make sure that the box is rectangular by placing some weights around if needed.

After this, you should wash **perfectly** one side of the two windows (the one that will be inside, the other side can be washed afterward).

Then make a large regular stripe of silicon glue on the center of the flap, on the half of the box (**the lower part** of the panel) and place delicately the window on it.



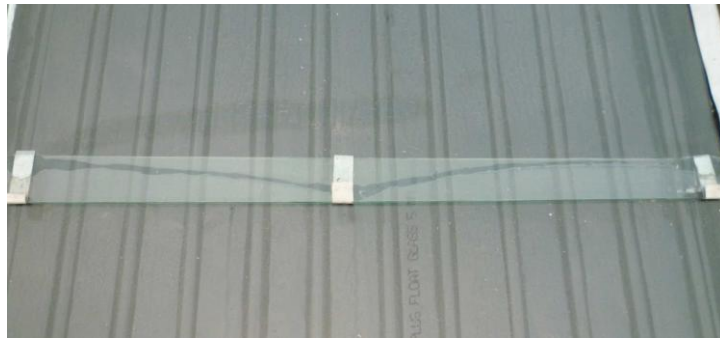
Then, you have to put some weights on the borders of the window to have a good adherence on the zinc (it is not compulsory to put as much weights as on the pictures below). Be careful to not brake or scratch the glass (you may put some wood under the weights to protect it). It is possible to add some little zinc stands for the windows but it is not compulsory (see *V/ Different solutions and materials.*)



The first window is ready. You now have to put some silicon glue on the

second half of the box. Once again, you will try to make a large regular stripe.

The second window will overlap the first one of 4cm, on the middle of the panel, to avoid water infiltration. Therefore, you have to put some silicon glue on the upper part of the first window to fix the second one on it. You can make a V form with the silicone (as below) and later if needed make a little hole in the bottom of it with a blade. This is to allow the evacuation of an eventual water condensation on the upper window.



Then, put delicately the second window exactly on the borders of the box. Finally, as for the first window, put some weights over it, including the middle part (but be careful, this part is very fragile).



You may also add some silicon glue around the inlet and outlet of the pipe system to assure the impermeability of the box.



You should not touch or move the panel for seven days from now; indeed, it's the time the silicon glue takes to dry completely and to achieve maximum resistance. The panel should also be safe from rain or humidity during this period.

### **3) The hot water tank**

#### **a/ Preparation of the tank**

##### ***Tools and materials:***

- Metal saw*
- Hard brush and soap*
- Thick plastic tank for chemicals (100 to 150 liters)

The hot water tank can be made out of several types of drums but it has to be resistant to corrosion (rusting) and high temperatures (at least up to 70°C). In our case, we will use a second hand thick plastic tank used for chemicals product. If you want to use another type of tank, you can refer to the end of the manual (*V/ Different solutions and materials*).



You need to be able to reach the inside of the tank, so if it doesn't have a big cover you will have to cut it the higher possible (you can use a metal saw). Nevertheless it is better if your tank has already a big cover because when you cut it by yourself the tank can be deformed afterward.



Then, wash the inside of the tank conscientiously and several times, especially if it was used to store chemicals. You should not use a tank that has stored some dangerous or hazardous chemicals anyway.

## **b/ Inlets and outlets**

### ***Tools and materials:***

- Blade or sharp knife
- Drill or piece of GI pipe heated (to make the holes)
- Measuring tape
- Two pipe wrenches or spanners
- Rubbing paper
- Threading tape
- Two tank-nipple 1inch, one  $\frac{3}{4}$ inch and one  $\frac{1}{2}$ inch

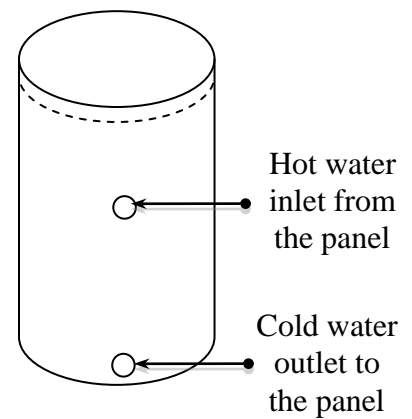
Now, you have to make five holes in the tank at the right places. They are made for: the cold water inlet, the hot water outlet, the panel(s) inlet and outlet (to assure water circulation) and a drain in case you need to empty the tank. This part is very important and not so easy to understand so pay attention to what will follow.

You can decide to make the holes on the height of the tank, as will be presented below, or on the bottom of it. If you want to know more about it, please refer to chapter V/ *Different solutions and materials*.

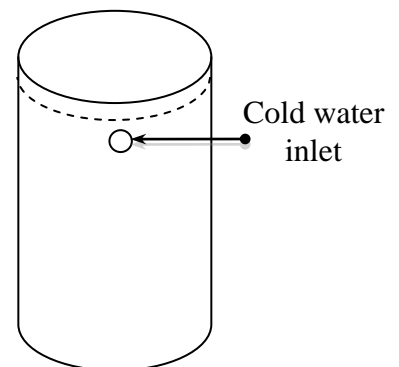
On the horizontal plan, around the tank, the holes can be at different places depending on each installation and will not affect the efficiency of the solar water heater. At this time you should know the future place of the hot water tank, the panels, the cold water supply and the hot water outlet. Therefore, you will try to place your holes where it's easier for you to connect these elements on the hot water tank.

But in the vertical plan, on the height of the tank, it has to follow some conditions.

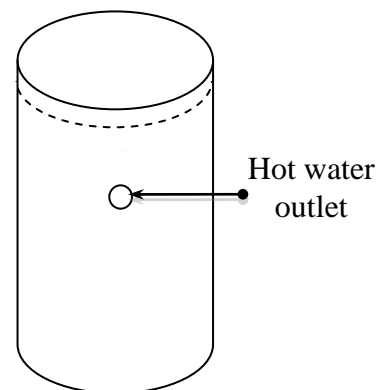
First, the inlet and outlet for the panel(s) (one-inch diameter). One (the way for the cold water) has to be almost at the lower point possible (5cm of the bottom for example). The other one will be placed around the three quarters of the tank height. In fact, it needs to be high for the thermosiphon to work well but to be always under water to keep the circulation (so not at the top).



Then, the inlet for the cold water (from your water supply) has to be done the higher possible on your tank, because you will put a floating valve (toilet system) to assure an automatic filling of the tank, this system will be explained in details in the next chapter. Around ten centimeters under the top of the tank is usually good but this can change in regards to your floating valve. Be careful that it is not too high so the valve cannot close (the ball can be blocked if it reach the cover). It should be in half-inch diameter but this depends on your floating valve (if you have any doubt, please refer to *III/3)c/ Automatic filling* ).



The hot water outlet (that will lead to your shower) has to be high enough to have always hot water (because as you know now, the hottest water is on the highest part). But you should understand that, because there can be more pressure in your shower tap than where the tank is filled up, the level of the water in the hot water tank can decrease for a while when you are taking your shower. So your hot water outlet must not be too high if you want to have always water in your shower. That's why we will place this hole around the three quarters of the tank height (**but it has to be higher than the panel's outlet**). That will give you enough water to shower and will give the time to the tank to fill up again between two showers.



Finally, you may want to add a drain outlet to be able to empty your tank. It will be on the bottom of it. A half-inch diameter hole should be enough.

Now you know where to make the holes, so let's go! You can use a hand (or electric) drill but if you don't have any, it is as easy to do them by heating a metal pipe and pushing it through the plastic. Then you may take out the plastic surplus with a sharp knife and rub the border of the hole with rubbing paper to have a good shape.



When your holes are perfect, you can insert and tighten the four tank nipples with two spanners. **Do not tighten the tank-nipples too hard** otherwise you will crush the joint and it will have some leaking. You have to put the part of the nipple that has to be screwed (the mobile part) **outside the tank** to be able to fix the plumbing extensions by the outside afterward (when the insulation will be placed, you will be able to hold the tank nipple only from the inside of the tank). The cold-water inlet hole doesn't need any tank nipple thanks to the automatic filling system that we are going to see in the next part.



Then, you have to put some threading tape on the outside part of the tank-nipple (always in the screwing way, clock side). We advise you to put a good quantity of threading tape on this part because it will be very difficult to fix if there is any leaking. **Don't forget to do it before placing the insulation because you will not be able to do it afterward. If it is the first time you put some threading tape, there is more explanations to help you in Annex.**

## c/ Automatic filling

### **Tools and materials:**

- Two pipe wrenches or spanners
- Threading tape (Teflon)
- One floating valve
- A piece of garden pipe and a round metal fixer and/or a piece of ½inch GI pipe welded

For several reasons, the hot water tank must be always full. Indeed, the level has to be sufficient to take water for the shower (the hot water outlet being quite high) and also to let the water circulate. To be sure this is always the case, we will put a floating valve that will cut the inlet of water when the tank is full. There is at least one other way to do achieve this automatic filling but it needs a lot of changes on the present system, if you want to know more about it, please refer to chapter *V/ Different solutions and materials*.

One problem is that, by this way, the cold water will enter on the top of the tank and mix with the hot water. This can be annoying especially when you are taking your shower, that's why it is better to add a pipe that will lead this cold water to the bottom of the tank.

This pipe can be made out of garden pipe fixed with a metal ring or by welding an iron pipe to the bottom of the valve.



Now you can install your enhanced floating valve (don't tighten too hard), and **put some threading tape on the outside of it.**

## d/ Insulation

### **Tools and materials:**

- Blade or sharp knife
- Measuring tape

- Wood glue (*Fevicol*) and paint brush (wash with turpentine oil and then soap and water after use)
- Sticking tape
- Some plastic string (around 6 meters)
- Aluminum foil (9 meters)

You now have to insulate your hot water tank. We will use the same foam than in the panel. As for the insulation of the panel, we could use many different materials. To know more about it please refer to chapter *V/ Different solutions and materials*.



First, you may put some aluminum paper around the tank (the bright side looking inside) to help insulating by reemitting a part of the infrared rays to the hot water. You can fix it with some wood glue and sticking tape.



Then, put your insulation around the tank. Don't forget to make holes in the foam for the inlets and outlets. To have a good insulation you need around five centimeters all around (if your storage is bigger, you can increase the insulation). In our case, we have a roll of 12mm thick foam and we will make four turns around the tank, so almost 5cm of insulation in total. You can fix the insulation with a strong string.



Now, you can prepare the insulation of the bottom and the top of the tank. For this purpose, you will cut at the right size several pieces of insulating foam to have the good insulation height. As the top of the tank is hotter than the bottom, we will insulate it better. We advise at least 4cm on the bottom and 6cm on the top.

As always, you can use different types of insulation. In this example, we will also use some polystyrene (thermocool), which is a very good insulator and can be easily found for free.



## e/ Tank protection

### **Tools and materials:**

- Two hammers (or a riveting-machine)
- Metal pliers
- Measuring tape
- A piece of wood
- Big rivets
- Three pieces of old corrugated sheet of 4feet by 3feet each
- Plastic foam 12mm thickness (8 meters)
- Small piece of zinc sheet
- A few nails
- Plastic string (5 meters)
- Some pieces of polystyrene (not compulsory)

We have to make a box to protect the tank and its insulation against aging (especially sun and rain). As for the panel's box and the insulation, this box can be made of different materials (see *V/ Different solutions and materials*). In our case, we will use a second hand iron sheet (corrugated iron) for the outline of the box and some pieces of metal sheet for the bottom and the top.



For the outline it is quite simple, you need a piece of metal of the good dimensions. The height will be the hot water tank height plus ten centimeters of insulation (about one meter height for a 100L tank), and the width will be the perimeter of your tank plus five centimeters insulation. To calculate the perimeter (length of the outline) you have to calculate the hot water tank diameter (distance between two opposite borders), then add  $2 \times 5 = 10\text{cm}$  (insulation) and multiply by 3,14 (Pi) (you will take it a bit bigger to be sure). For example one tank has a diameter of 50cm, I do  $(50 + 10 = 60 ; 60 \times 3,14 = 188,4)$ , so the perimeter is 188,4cm and I will take a sheet of around 2m to be sure its big enough.

In our example, we will take 3 pieces of 120cm by 80cm and rivets them together to make one piece of more or less 120cm by 2m (if 120cm is too high, you can cut or bend the surplus).

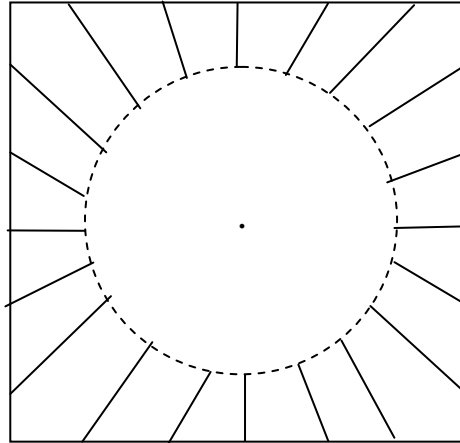
If you prefer, you can fix it together by nailing the sheet on a piece of wood instead of using rivets.

If, as in our example, the iron sheet is corrugated, you absolutely have to take it by the length (as on the picture above); otherwise it is impossible to give a good form.

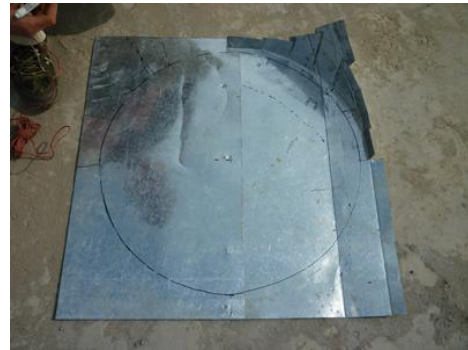
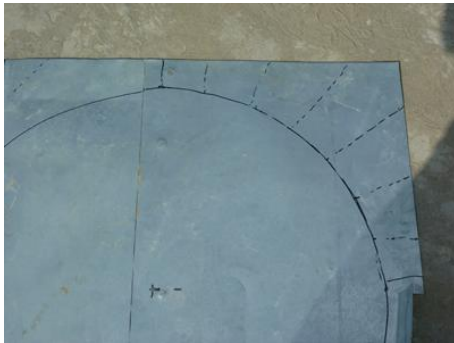
A little tip: when you must rivet a very soft metal (as an old corrugated iron sheet), it is easier to place a little piece of harder metal (zinc for example) on each side of the sheets, as on the picture below.



To make the bottom of the box, you may use a square piece of zinc, aluminum or whatever, on which you will draw this:



Then you only have to cut on the marks and to fold on the dotted line. The size of the circle should be the same than the bottom of your box. You can make a little hole with a nail on the middle of the circle to evacuate an eventual infiltration of water.



And finally, you can rivet it inside of the box (four rivets on the high points should be enough).



For the cover, you can use a second hand aluminum sheet, as below.



Now the box is finished; you can put the bottom's insulation.



And then you can put your tank in your box to check the position of the inlets and outlets. Then, you can make the holes for them at the right place on your box.



## f/ Plumbing extensions

### **Tools and materials:**

- Two pipe wrenches
- Threading tape
- Draining outlet (1/2inch): two sockets, one 3inch nipple and one male cap
- Panel inlet outlet (1inch): one socket, one 3inch nipple, one elbow, one 2inch nipple, two unions
- Cold-water inlet (1/2inch): same than above but in 1/2inch and you can add a nipple and ball valve
- Hot water outlet (3/4inch): one socket, one 3inch nipple, one elbow, two 9inch nipples, one ball valve, one non return valve, two 2inch nipple, one tee, one union.

Now, you have to prepare the plumbing extensions that will connect the tank to the cold water supply, the panel(s) and the shower. **You first have to make the extensions entirely** before tightening them on the tank, otherwise you will force on the tank nipple each time you add a piece.

You will start all you extensions by a 3-inch long nipple and a socket (as below) that will go inside the insulation. If you made the holes in the sides of the tank (as in our example), you will need to add an elbow to go down.



### **Draining outlet:**

- 1/2inch diameter is enough.
- You only need to close it by putting a socket and a male cap.



### **Inlet and outlet for the panel:**

- Always in 1inch diameter** (like the horizontal inner pipes of the panel).
- You only need a GI union to fix your PEHD pipe and to be able to disconnect the panels from the tank.



### **Cold water inlet:**

- Normally in 1/2inch but depends on your floating valve.
- You only need a GI union to be able to disconnect it but you can add a ball valve to be able to close the inlet from the tank.



### **Hot water outlet:**

- Its size depends on the number of bathrooms that you plan to connect to the solar water heater. A 1/2inch diameter is enough for a single shower, 3/4inch for two showers and 1inch up to four (even more if the showers will not be used at the same time).
- You need: one ball valve to be able to close the outlet, a non-return valve (to prevent cold water to enter the tank due to mixing valve in your shower) fixed after two long nipples (9inch long) otherwise there will not be enough water pressure to open the non-return valve (but these long nipples are not needed if the outlet has been done on the bottom of the tank) and a GI union to be able to disconnect it. You can add tee

that will be closed with a male cap on one end to be able to add one hot water pipe later (this has to be placed after the non-return valve).

Now, you can place and tight these extensions **by holding the tank nipples by the inside of the tank** with a pipe wrench or a spanner.



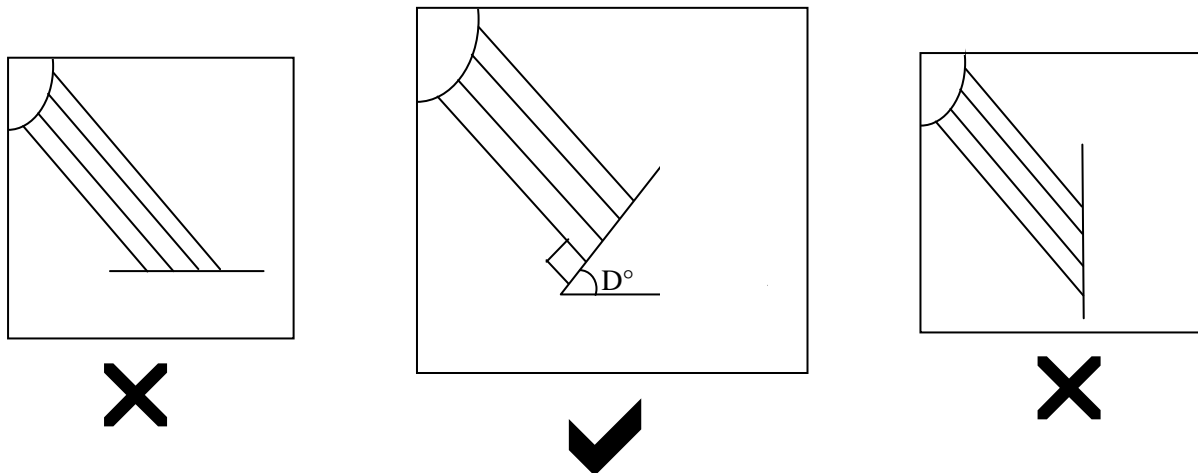
You have now a solar panel and a hot water tank, both ready to be installed.



## **4) Installation**

### **a/ Standing structures, inclination**

There are some things you should know about the inclination of a solar panel. First, in the case of a thermosiphon system, the inclination will allow the water to circulate. Indeed, if the panel is flat on the floor, the hot water will not go naturally at the top of the panel. Moreover, a good inclination will enhance considerably the efficiency of the panel because the maximum output is reached when the sunrays are exactly perpendicular with the panel.



The best average angle degree of inclination ( $D^\circ$ ) for an all year long utilization is the latitude of the place where you live. For example in Nepal, the latitude is around  $25^\circ$  so the inclination angle ( $D^\circ$ ) would be  $25^\circ$ . But if the solar water heater is only used in wintertime the inclination can be increased of 5 to 15 degrees to enhance efficiency during this period. The explanation is that by the solstices (21 June and 21 December), the sun has angle difference of  $23^\circ$  (lower in winter and higher in summer) with the equinoxes (21 March and 21 September). So for example in Nepal ( $25^\circ$ ) the sun angle will be from  $2^\circ$  (middle of summer) to  $48^\circ$  (middle of winter) all along the year.

But as we said before, don't forget that the panel must have at least a little inclination to allow the thermosiphon circulation and also to let the rainwater flow down on it, so do never put the panel flat ( $0^\circ$ ).

When you know what is the best inclination for your system, you can make (or order to a professional) the structure that will hold your panels, and at the same time the structure that will hold the hot water tank (that has to be higher than the panels, as we said before). This is not compulsory in all cases. As we said in the *Preparation and location* chapter, you can maybe choose a place where you don't need any stands.

We are giving details of one type of standing structure in annex, but you are free to do your own or to find another way to hold your panel(s) and tank.

Little tip: to make a structure for the panel that has an inclination of **30°**, if my panel is **2meters** long:

-the height of the structure will be  $2 \cdot \sin(30) = 2 \cdot 0,5 = 1$  meter

-the length (on the floor) of the structure will be  $2 \cdot \cos(30) = 2 \cdot 0,866 = 1,73$  meter

## **b/ Tank-panel connection**

### ***Tools and materials:***

- Two pipe wrenches
- Measuring tape
- Metal saw
- Threading tape (Teflon)
- Plastic foam 5 or 8mm thickness (3 meters)
- PEHD pipes 1inch \* 4m
- Iron wire or plastic string
- Sticking tape
- Two 1inch elbow
- Two 1inch per 2inch nipples
- Two 1inch unions
- Two 1inch socket
- Two 1inch male cap

Now that the silicone is dry, you have one or several panels and a water tank fully ready. Therefore you can install them at their definitive place and prepare the pipes that will connect them together.

To connect the hot water tank and the panel(s) together, we will use some PEHD pipes of 1inch diameter. We will connect them with some GI unions. You can directly screw the union on the pipe. You can use different materials to connect them, see chapter *V/ Different solutions and materials*. Some materials are better, stronger and easier to use than PEHD pipes, but often more expensive. You shall get informed on the possible solutions wherever you live.

It is better to connect the hot water up on one side of the panel(s) and the cold water down on the other side of the panel(s) (as on the pattern below). It is possible to fix them on the same side if really needed but the thermosiphon circulation will be less efficient.

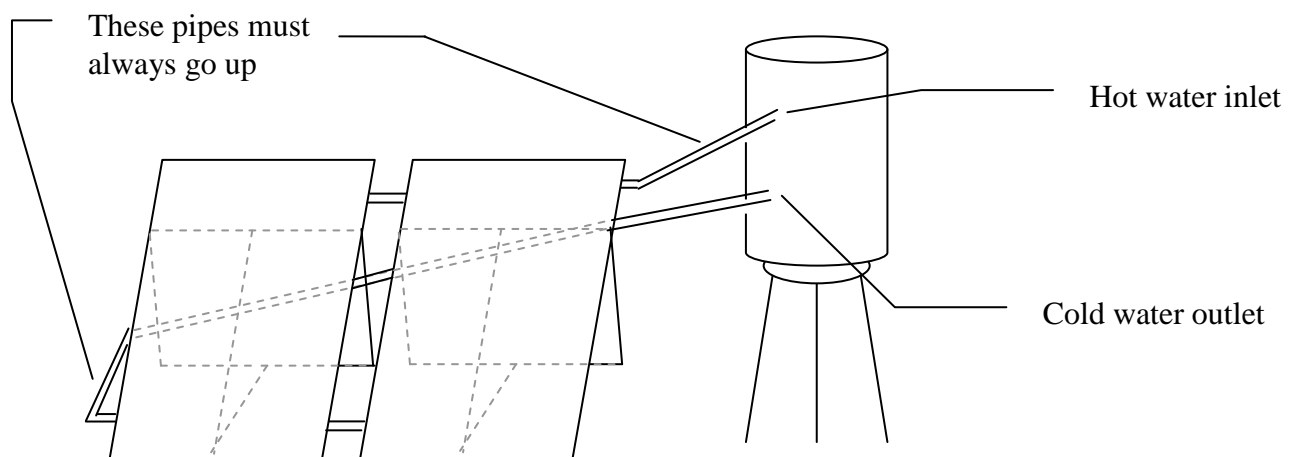
So there is two outlets left unused on the panel, they are made to make you able to connect one or two more panels on your system if needed later. However, you now need to close them. For this purpose you can use a socket with a male cap.



Then, you need to fix some GI unions (after one elbow) on your panels outlets. Then, take the exact measures of the lengths needed between the unions (counting the threading) and cut the PEHD pipes at the right length. Continue by screwing the unions on the pipes, as below:



And then you can connect the panel(s) to the hot water tank and check if your pipes are really at the good size (cut or make new ones if needed). Cold with cold (down tank to down panel) and hot with hot (up tank to up panel), as below. The pipes must always go up from the panel to the tank. You can add one GI elbow on the PEHD pipes when a turn is required (instead of twisting it) to prevent from forcing on the threading (which can lead to leaking).



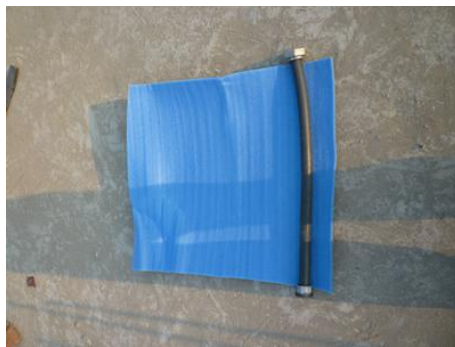
If you want to be sure that there is no leaking, you should take out the threaded pipe from the union and add some threading tape on it (but not on the two first thread lines). Then you can put the pipes back in place (you can insulate them before). You should also avoid curving or bending the PEHD pipes, and keep them always straight; otherwise they could disconnect themselves after some time. To avoid these problems, you can use other materials as high temperature PVC pipes or even GI pipes.



The pipes that will connect the tank and the panel will have some very hot water inside them; therefore they must also be insulated to limit the heat losses and increase the efficiency of the system.

For this purpose, we will use the same kind of foam than previously, but a thinner one to be able to bend it easily. A thickness of 5 to 8mm is a good choice. As always, you can find other solutions in chapter V/ *Different solutions and materials*.

You now have two options: you can insulate the pipes directly or dismount the pipes, insulate them and then connect them back. This will maybe take some more time but will be easier to do and will probably make a better result.



You must cut your pieces of insulation of the same length than your pipes and large enough to make two or three turns around the pipe. Indeed, we advise to put at least 15mm insulation.

To fix the insulation, one way to do is to put some electric sticking tape around some pieces of iron wire (so it doesn't cut the foam and resists better) and tight them around the insulation. You can add some sticking tape between the pieces of iron

wires if the shape is not good enough.



Then you may add some aluminum paper (bright side looking inside).



And finally, we add a plastic sheet that will protect our insulation against aging. You can fix it also with your special iron wire and some scotch tape.



It is possible to insulate some long pipes. In this case, it is easier to use several pieces to do the length. Then cover the space between two pieces with another one.



If you put several panels, you may insulate the pipes that are connecting them together.



You now can connect definitively the panel to the tank.





### c/ Windows protection

#### **Tools and materials:**

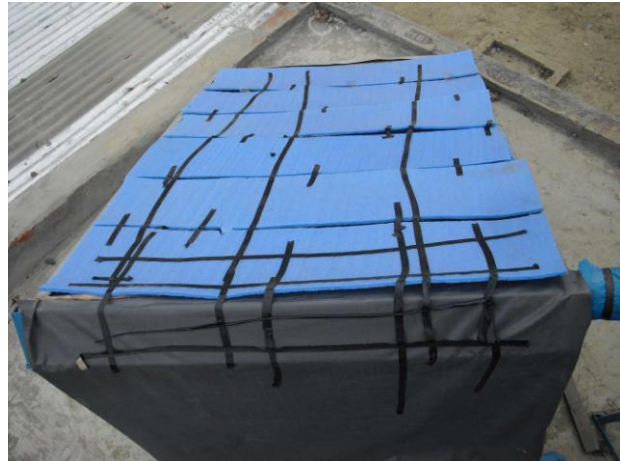
- Blade or knife
- Measuring tape
- An Elastic for clothes (2 meters long)
- Canvas sheet or opaque thick cotton cloth, 1 per 2,5 meters
- Iron wire or plastic string
- Sticking tape

When there is no water available or when the solar water heater will not be used for a long period (summer for example), you must add something to cover the panels (otherwise it could overheat).

You can use an opaque canvas sheet or a dark and thick cotton cloth and fix it with a cable wire or something else that will withstand long sun exposition (the plastic stripe on the picture is not the best option).



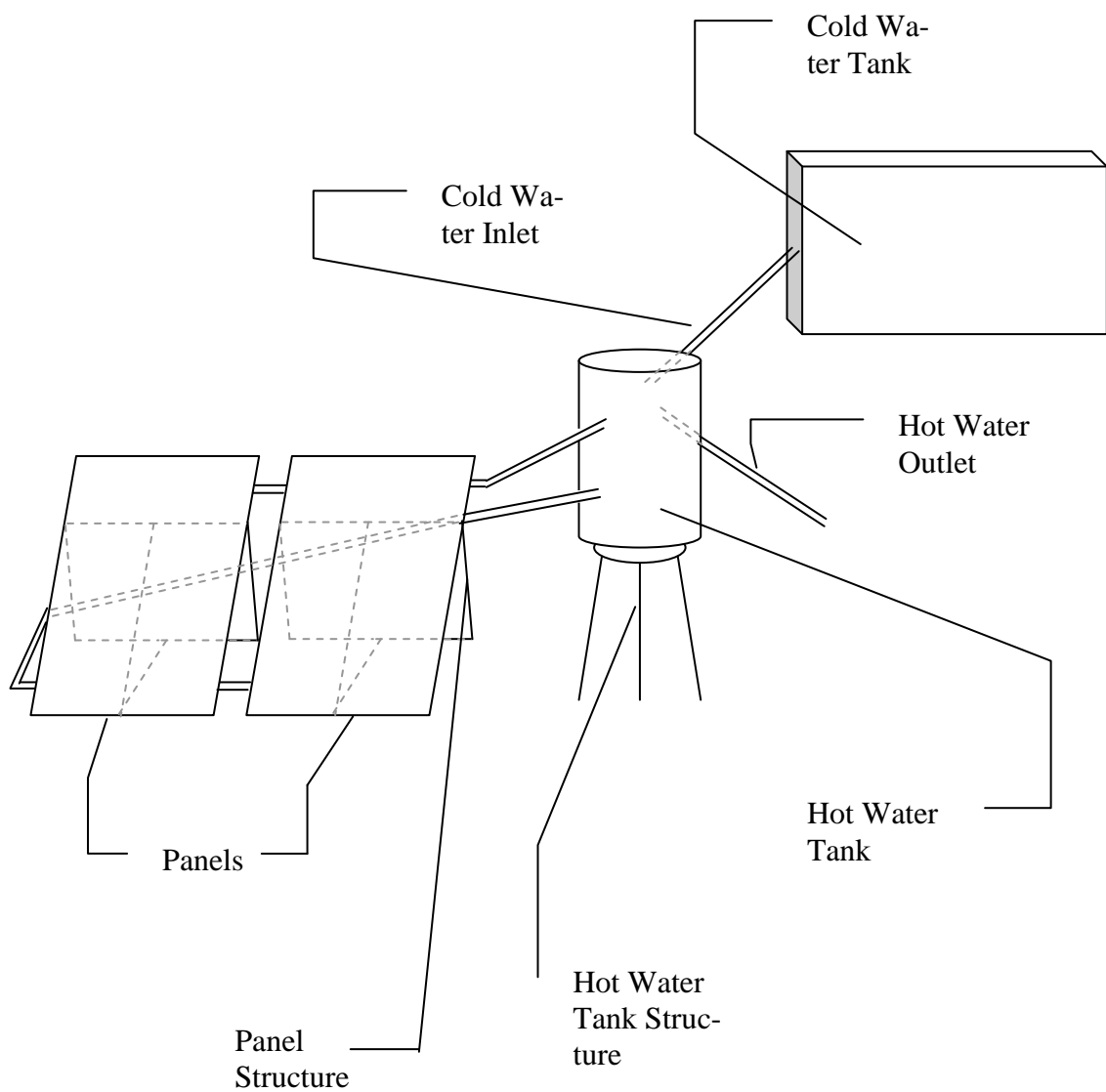
You may add some pieces of insulation foam under the canvas sheet to prevent it from overheating and protect the windows from stones etc. You can sew the pieces together with a string, and even sew them to the covering sheet, (it will stand better than with the scotch tape on the picture).



Last but not least, you can connect the hot water tank to your cold water inlet and to the hot water outlet (to the showers). **Note that you should also insulate the hot water pipes that lead to your shower(s), especially if the length is important.**

And you have now a brand new solar water heater fully completed and installed and all of it made by yourself!

# SOLAR WATER HEATER GLOBAL PATTERN



## **IV/ UTILIZATION GUIDE**

### **1) Optimal usage, maintenance**

There are some recommendations and tips which if followed can go a long way to improve the overall efficiency and lifetime of your solar water heater. They are sorted by approximated order of importance.

**If your water supply is empty, it is very important to cover the panels** to prevent from overheating.

**If you are not going to use the hot water for a long time** (holidays, summer time...) you should also cover the panels. Keep the solar water heater full of water even if not in use and covered. It is also better to take out some water from it at least once on month to make the water circulate in the pipes. All this will improve considerably the lifetime of your solar water heater.

**Clean the windows regularly:** If dust and dirt are allowed to settle on the glass, it will block the sun's rays and reduce the efficiency of the system. It is advisable to clean the windows every one or two weeks with fresh water or soft cloth.

**Regularly inspect the solar water heater** to make sure it's not damaged and that there is no leaking. Also check for any rusting in the plumbing lines and do necessary repairs. If you have any problem, you can find a solution in the trouble-shooting part of the manual.

**It is advised to paint the iron support stands (if you have any) every four or five years.**

**If your water is very hard or dirty**, you should check once a year if there is not too much deposit in the water tank and clean it if needed. You may also clean the pipe system with hydrochloric acid every few years, depending on the hardness of your water.

## 2) Trouble-shooting

You now have a brand new thermosiphon solar water heater. We advise you to let it work under the sun a few days and to check if everything is going well. This chapter is made to help you to solve some problems that you could have.

Problem	Cause	Remedy
<b>Water is not coming from the tap.</b>	a) No cold water supply (the overhead tank is empty). b) Cold water inlet valve is shut. c) Air is trapped in the hot water pipe line. d) The float valve is stuck by sediments or scales. e) Non-return valve stuck. f) Cold water inlet pipe or hot water outlet pipe is choked by sediment or scales.	a) Make sure there is a water supply or cover the panel(s) if not possible. b) Open the valve. c) Open the hot water outlet pipe near the valve and try to remove the air . d) Clean the float-valve or replace it. e) Clean the NRV or replace it. f) Clean the pipes with long wirebrush or change them.
<b>Not getting hot water.</b>	a) Cloudy day, not enough sun light. b) The solar water heater is not receiving enough sun light. c) Excessive water consumption (you used all the hot water). d) Cold water pressure due to mixing valve preventing the hot water coming through. e) Thermosiphon problem.	a) After the rain comes the sun ! b) Relocate in unshaded area or cut the branches or else that make shade. c) Plan your water usage and consumption as per installed capacity or wait some time (under the sun) until it's hot again. d) Run hot water slowly at first and then gradually open up the cold water tap for optimal mixing of hot and cold water at the point of use. <b>You must have a non-return valve on the hot water pipe!</b> (you can check if it is not broken) e) Make sure that the pipes between the panel and the hot water tank are always going up, as explained before, and that the hot water tank is <b>higher</b> than the panels.

<b>Problem</b>	<b>Cause</b>	<b>Remedy</b>
<b>The water is only luke-warm.</b>	a) Cloudy day, not enough sun light. b) The solar water heater is not receiving enough sun light. c) Windows are dirty. d) Excessive water consumption. e) Hot water pipes are too long or not insulated properly. f) The solar water heater is undersized (the tank is too big or the solar panel is too small).	a) After the rain comes the sun ! b) Relocate in unshaded area or cut the branches or else that make shade. c) Wash the windows. d) Plan your water usage and consumption as per installed capacity or wait some time (under the sun) until it's hot again. e) Insulate properly the hot water pipes and make them shorter if possible. f) Decrease the size of your tank (or the amount of water by the floating valve) or add another solar panel.
<b>Large drop in overnight temperature</b>	a) Ineffective insulation. b) The insulation is wet and therefore not insulating properly. c) Excess heat loss in hot water pipeline.	a) Check the insulation around the storage tank and change or increase if necessary. b) Ensure that the insulation is dry. It can be due to rain leaking or to a bad adjustment of the floating valve. c) Insulate properly the hot water pipes and make them shorter if possible.
<b>Hot water flow is irregular.</b>	a) Air is trapped in the hot water pipe line. b) Cold water inlet pipe inside tank choked by sediment or scales. c) Cold water inlet is slower than hot water outlet (due to floating valve).	a) Open the hot water outlet pipe near the valve and try to remove the air . b) Clean the pipe with long wirebrush. c) Change the floating valve for a bigger one or wait a few minutes between two shower so the tank is filled up again.
<b>Something else is going wrong.</b>	a) There is a leaking. b) The windows are broken. c) The hot water tank overflows : the floating valve is stuck.	a) Drain the system, let dry, and put some epoxy putting on the leaking. b) Try to fix them with some glue. Otherwise take the glass out by cutting the silicone glue with a blade, then wash the silicone and put some new windows. c) Clean and repair the floating valve or replace it.

## **V/ DIFFERENT SOLUTIONS AND MATERIALS**

The solar water heater that has been presented in this manual is only one out of the infinity of different possibilities. As we want to be the more exhaustive possible we will present in this chapter some different solutions and materials that you can use to construct your own solar water heater. These variants can make the construction cheaper, stronger and easier for you if you choose well.

Finally, once you understood well the solar water heater working principles you can almost invent your own system. But keep in mind that the water should raise frequently at 50°C minimum during at least one hour to avoid bacterial development, in particular legionella which could be dangerous.

To illustrate these words, there is an example of a solar water heater made almost entirely in recuperation materials (so it almost didn't cost anything). The box is an old wooden transport stand; the pipe system made of a garden pipe; the windows are some pieces of Plexiglas...



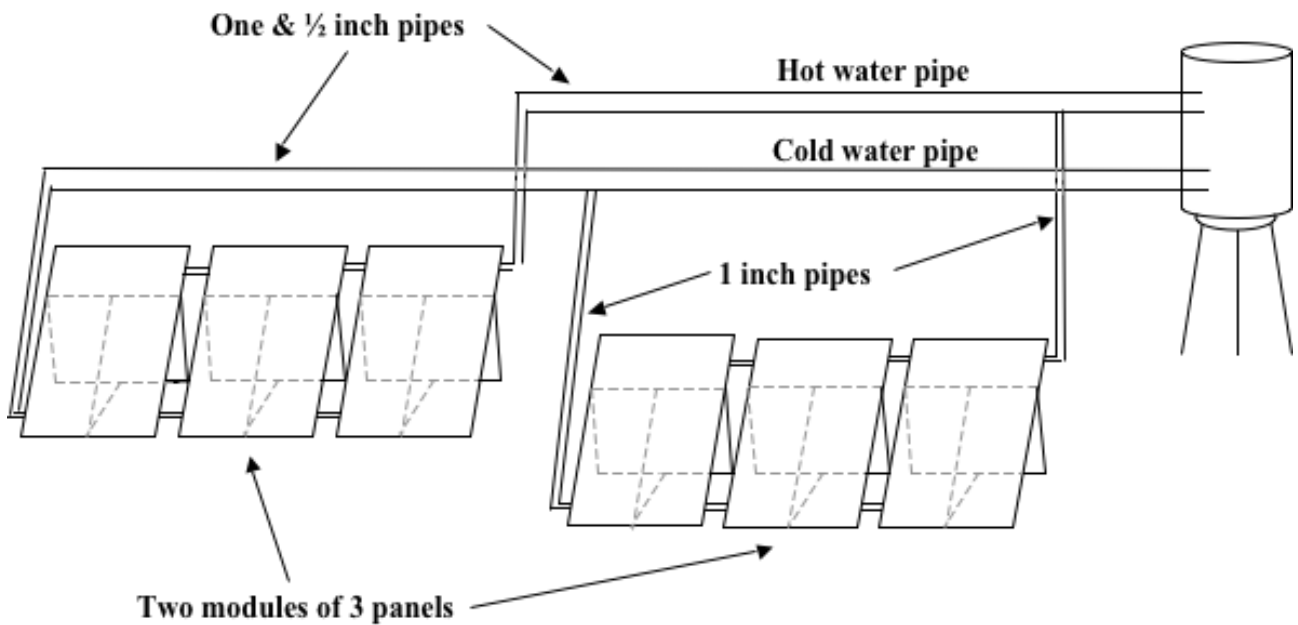
### **To connect several panels together:**

As we explained before, if you want to increase the capacity of your solar water heater you will have to construct more panels and connect them between each other. There are some things you should know if you want to do so. One example of the materials required for a 200L solar water heater is given in Annex.

- ⇒ One panel is developed to heat 100L of water in Chitwan, Nepal (latitude around 25°). So if you want 300L of hot water you will have to connect 3 panels together. It can change in regards to your location (a northern country will probably need a bigger surface to heat the same amount of water and vice versa) and to the efficiency of your panel.
- ⇒ To connect a panel with another one, you only need to put some GI unions on the threaded part of the pipe systems and to tight them together. Be careful also to weld your pipes at the exact same size so they fit together.



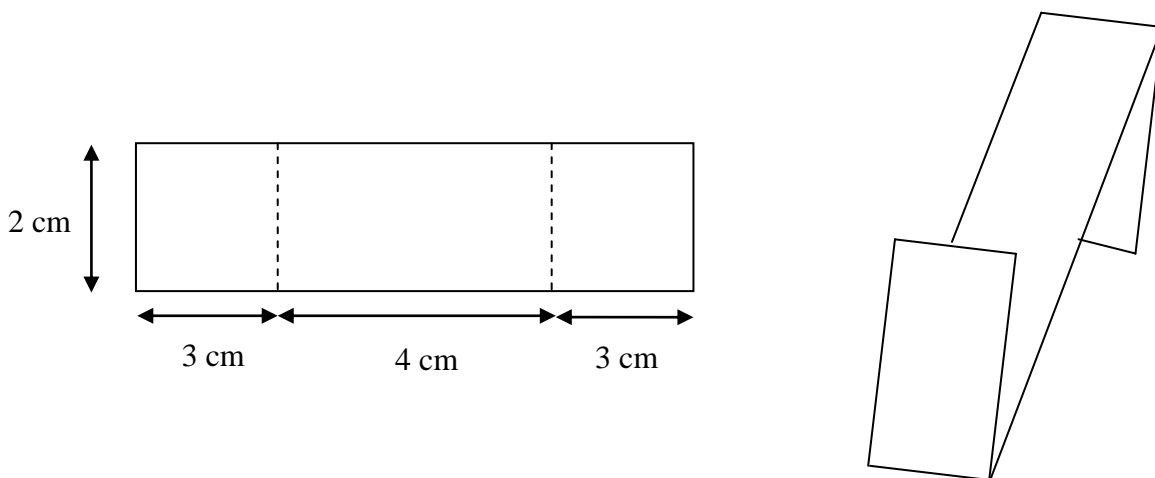
- ⇒ You should not connect more than 3 panels directly together. If you want to have more than 3 panels, you should connect them 3 by 3 or 2 by 2 and to connect these different modules on two bigger pipe which will be connected to the hot water tank. The cold one, going from down tank to down panels and the hot one, going from up tank to up panels. For 2 modules of 2 or 3 panels, you can use some 1,5inch pipe; for 3 modules some 2inch pipes etc.



## Windows:

- ⇒ It is possible to use a single big window for each panel by using some Plexiglas, which is less fragile than the regular glass. Nevertheless, the Plexiglas is more expensive and can lose transparence after some time.
- ⇒ You can put a double-glass for a better insulation of the solar panel and therefore a better efficiency.
- ⇒ It is possible to put the windows over some rubber instead of using silicon glue. The panel's box will maybe have to be rethought in this case. For example, you will have to add some little stands for the windows.

Take a piece of zinc of 2 by 10cm and fold it as below.



You must do three zinc supports as this one and place them one at the center and the others near the borders of the window, without folding totally the last part.

Then put some silicon glue under to fix them and to assure the impermeability. You have to do the same for the down of the box.



- ⇒ If there are some important risks for the solar panels (monkeys, hailstorms...) in your locality, you can add a protection mesh over them.

## Insulation:

There are plenty of possibilities to make your insulation but it is always better if it is natural or from recycling. We give you some examples of insulation with their advantages and inconveniences.

- Wool** (from sheep, yak or whatever). Light and can be cheap but will not resist to parasites more than 3 years if it's not treated.
- Straw or hemp**. Light and very cheap but will be damage by humidity and parasites.
- Ashes**. Very heavy but free of cost.
- Crushed glass**. Recycling but heavy.
- Soil or adobes** (good to mix with straw). Heavy but free of cost.
- Polystyrene** (thermocol). Light, can be found for free (recycling).
- Glass wool**. Light but will be damaged by humidity.
- Any kind of **insulating foam** resistant to humidity
- And many others...

**Keep in mind that you can use several insulations together!**

## Pipe insulation:

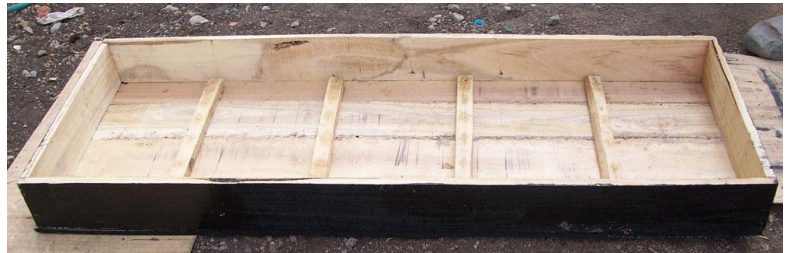
You can use all the materials mentioned previously to insulate you pipes. For example, it is possible to use some wool wrapped around the pipes and protected with a plastic.

If it is available in your locality, you can buy some special pipe insulation tubes. It will be very efficient and easy to place but probably more expensive.

## Panel's box:

- ⇒ The panel's box can be made in a lot of different ways, regarding to the materials available and of course your inventiveness (wood, metal drum, soil...). But keep in mind that the lifetime of your box will change in regards to which material you used.

Example of wood boxes:



## Pipe system and aluminum sheet:

- ⇒ It is possible to use different metals to make the pipe system and the metal sheet underneath (the four best metals in order from the best: silver, copper, gold, aluminum). A pipe system in copper will have a far better efficiency but will be a lot more expensive.
- ⇒ You can make the pipe system out of one single pipe but it has to go always up for the thermosiphon to work (as on the first example given in this chapter).
- ⇒ You can make the pipe system by threading the pipes together but you need to be able to thread in reverse way to complete the system.
- ⇒ You can also make a pipe system out of another material (PEHD for example) but it will affect considerably the lifetime of your solar panel. For example, the PVC pipe system (1/2inch) that is presented below will not resist more than 6 month. **You should use some more resistant plastic or/and thicker** (in 2inch diameter for example the PVC can resist a lot longer).
- ⇒ You can make another form than a pipe system, like a flat impermeable box.

Some (bad) examples:



PVC pipe system



Single plastic pipe system



Metal box system



Thread GI pipe system

⇒ You can add two pieces of aluminum sheet up and down of the pipe system to increase the surface receiving the sunrays (if you have enough space in your panel's box), as below.



## Tank:

- ⇒ You can use several types of tank. It has to resist against high temperature and corrosion (rusting). Either plastic or iron tank will need to be several millimeters thick, one to resist to high temperature and the other to resist to rusting.
- ⇒ You can make a pressurized tank (out of thick iron sheets welded together for example), which will not need any floating valve. In fact, a vent pipe will be added instead, to control the level of water and protect from overheating. **But this vent pipe must also be insulated!** Indeed inside it will always be the hottest water of the system so it will lose some energy if not insulated. It is a very good and robust way to do a hot water tank, but it can also be very costly.
- ⇒ You can make all the inlets and outlets of your tank on the bottom of it (except the floating valve which usually has to be on top). Like this you can put the plumbing extensions before the insulation and slip everything in the zinc box.

It will also eventually evacuate more easily the air that could be blocked inside the pipes.

But, as you know, the hot water outlet and one of the two panels outlet has to be up in the tank (see *III/ 3) b/ Inlets and outlets.*) That's why in this case you must add some extensions inside the tank for these two outlets. Indeed, you will have to add on your tank nipples a socket and a piece of GI or PEHD pipe to take the water at the appropriate level.



⇒ If you made your outlets on the side of the tank, you can add some extensions to evacuate more easily the air that can be trapped in the pipes, as below.



## Tank cover:

It can also be made differently, for example with a canvas sheet:

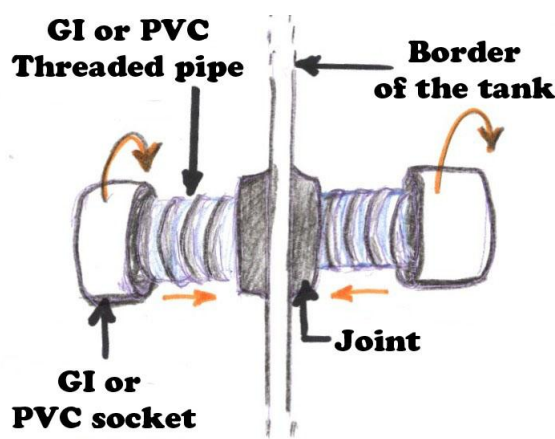


## Panel/tank connecting pipes:

You can use some GI pipes or any other kind of pipes but it has to resist to high temperature (and to be of one inch diameter).

## Tank nipple:

This is an example to show that you can always find a solution when you don't have the proper tool or material. If the tank nipples aren't available in your locality, you can make them as below (the joints can be made out of inner tubes of bicycle tire):



## Others:

- ⇒ In the case of using natural materials like wood or wool, you can treat them against parasites to increase their lifetime.
- ⇒ If you don't have any kind of cold water supply, the floating valve is no necessary. You will have to fill your tank by yourself (and adapt a rainwater recuperation system for example).
- ⇒ You can buy and add to your solar water heater an electric back-up system; which will heat the water when there is no sun.

## VI/ ANNEX

Pictures of several materials and tools (some can look different while you find them but be good as well):



Round metal fixer



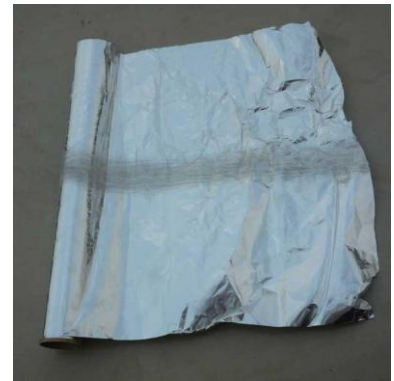
Floating valve



PEHD Tank



Glass sealant (silicone)



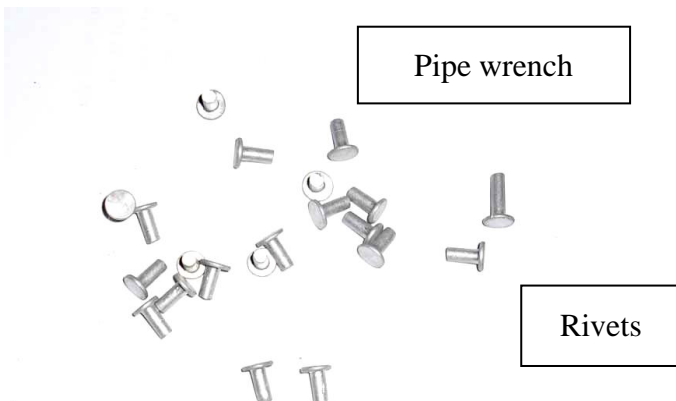
Aluminum foil



Pipe wrench



Metal scissors



Rivets



Insulation foam



Rubbing paper



GI Elbow



GI Nipple



GI Socket



GI Male cap



GI Union



GI Union disassembled



GI Tank-nipple



GI Tank-nipple disassembled



Non-return valve



Ball valve

## How to use the threading tape:

1. Hold the threading tape backside and start to turn around the threading of your male piece, **always in the screwing way (clock side)**.
2. Turn until you can difficultly see the threading (around twenty turns more or less depending on the thickness of the threading tape).
3. Fix on your female piece by tightening with two pipe wrenches. If your threading tape is well placed, it will force before the end of the threading and this will assure the impermeability.



Prices and materials for a Solar Water Heater with a lot of recuperation (100 to 150L; 1 panel; 1,7m<sup>2</sup>) in NEPAL (Sauraha, Chitwan)(**changes from classic SWH in bold**)

Materials	Quantity	Unity price (Rs)	Price (Rs)
<b>Pipes</b>			
GI pipes 1/2inch * 6m (good quality)	3	785	2355
GI pipes 1inch * 1m (good quality)	2	300	600
<b>Holes, threading and welding by yourself</b>	<b>1</b>	<b>200</b>	<b>200</b>
		Total pipes:	<b>3155</b>
<b>Panels</b>			
<b>Recuperated wood to make the box</b>	<b>1</b>	<b>0</b>	<b>0</b>
Aluminum sheet (0,1mm or thicker) 4*8 feet	1	550	550
Glass window 89*107cm thickness min. 5mm	2	600	1200
<b>Old pieces of plywood</b>	<b>1</b>	<b>0</b>	<b>0</b>
<b>Old canvas sheet</b>	<b>1</b>	<b>0</b>	<b>0</b>
		Total panels:	<b>1750</b>
<b>Insulation</b>			
<b>Polystyrene recuperated from packaging</b>	<b>1</b>	<b>0</b>	<b>0</b>
<b>Yak wool from your own yak</b>	<b>1</b>	<b>0</b>	<b>0</b>
		Total insulation:	<b>0</b>
<b>Water tank</b>			
<b>Second use plastic tank (100 to 150L)</b>	<b>1</b>	<b>0</b>	<b>0</b>
<b>Old corrugated sheet for the tank protection</b>	<b>1</b>	<b>0</b>	<b>0</b>
<b>A piece of iron bar</b>	<b>1</b>	<b>0</b>	<b>0</b>
<b>A piece of your garden pipe</b>	<b>1</b>	<b>0</b>	<b>0</b>
Tank Nipple 1inch	2	180	360
Tank Nipple 3/4inch	1	140	140
Tank nipple 1/2inch	1	90	90
Floating valve 1/2inch	1	180	180
		Total water tank:	<b>770</b>
<b>Connections:</b>			
Usual materials for connections	1	3080	3080
		Total connections:	<b>3080</b>

<b>Others :</b>			
Glass sealant (silicone <b>clear</b> ) tube 200ml	1	180	180
Black board paint 0,5L	1	100	100
Aluminum foil (for cooking) (*9m)	3	75	225
<b>A piece of grinding paper</b>	<b>1</b>	<b>0</b>	<b>0</b>
<b>A bit of petrol</b>	<b>1</b>	<b>0</b>	<b>0</b>
Small rivets (repeat) bags	1	40	40
Electric scotch tape	10	6	60
<b>Plastic string 20m</b>	<b>1</b>	<b>0</b>	<b>0</b>
<b>Iron wire 0,5kg</b>	<b>1</b>	<b>0</b>	<b>0</b>
Threading tape (PTFE, Teflon)	10	10	100
<b>A little bit of glue</b>	<b>1</b>	<b>0</b>	<b>0</b>
Round metal fixer	2	10	20
<b>One dozen of nails of several sizes</b>	<b>1</b>	<b>0</b>	<b>0</b>
		Total others:	<b>725</b>
		<b>TOTAL</b>	<b>9480</b>

Example of materials and prices for a 200 to 250L Solar Water Heater (2 panels ; 3,4m<sup>2</sup>) (**changes from 100L in bold**)

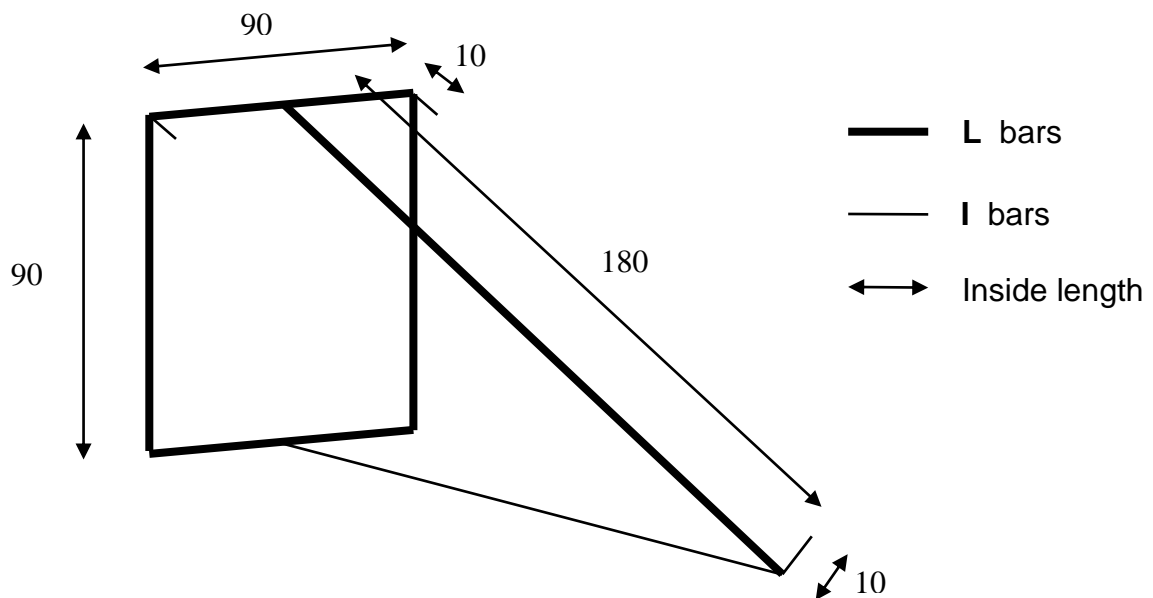
Materials	Qty	Unity price (Rs)	Price (Rs)
<b>Pipes</b>			
GI pipes 1/2inch * 6m (good quality)	6	785	<b>4710</b>
GI pipes 1inch * 1m (good quality)	4	300	<b>1200</b>
Hole making and Welding	2	1000	<b>2000</b>
		Total pipes :	<b>7910</b>
<b>Panels</b>			
Zinc sheet (0,3mm or thicker) 4*8 feet	2	750	<b>1500</b>
Aluminum sheet (0,1mm or thicker) 4*8 feet	2	550	<b>1100</b>
Glass window 89*107cm thickness min. 5mm	4	600	<b>2400</b>
Plywood sheet 3*7 feet (thinnest)	2	220	<b>440</b>
Plastic sheet opaque 1m*2,5m	2	150	<b>300</b>
*** (gray color foam, comes by big rolls)			
		Total panels :	<b>5740</b>
<b>Insulation</b>			
	(Me- ters)	(per meter)	
Plastic foam thickness 12mm ***	16	150	<b>2400</b>
Plastic foam thickness 8mm ***	4	110	<b>440</b>
*** (gray color foam, comes by big rolls of 1,4m high, take 12m of 12mm and 3m of 8mm)			
		Total insulation :	<b>2840</b>
<b>Water tank</b>			
<b>Thick plastic tank for chemicals (200 to 300 li- ters)</b>	1	1700	<b>1700</b>
Second hand metal sheets for the tank box	1	500	500
<b>PEHD pipes 1inch * 6m</b>	1	<b>300</b>	<b>300</b>
Tank Nipple 1inch	3	180	<b>540</b>
GI Elbow 1inch	5	80	<b>400</b>
GI Socket 1inch	5	70	<b>350</b>
GI Nipple 1inch * 3inch	3	45	<b>135</b>
GI Nipple 1inch * 2inch	6	35	<b>210</b>
<b>GI Nipple 1inch * 9inch</b>	2	<b>180</b>	<b>360</b>
GI Male cap 1inch (to close pipe)	2	30	60
GI Union 1inch	7	115	<b>805</b>

<b>Ball Valve 1inch</b>	<b>1</b>	<b>200</b>	<b>200</b>
<b>Non Return Valve 1inch</b>	<b>1</b>	<b>250</b>	<b>250</b>
GI Nipple 1/2inch * 3inch	2	30	60
GI Nipple 1/2inch * 2inch	2	25	50
GI Union 1/2inch	1	80	80
GI Elbow 1/2inch	1	50	50
GI Socket 1/2inch	3	40	120
GI Male cap 1/2inch (to close pipe)	1	10	10
Ball Valve 1/2inch	1	10	10
Toilet valve system 1/2inch	1	180	180
GI pipe 1/2inch * 2 feet	1	200	200
Garden pipe 1inch * 1,5m	1	100	100
		Total water tank :	<b>6670</b>
<b>Others :</b>			
Glass sealant (silicone clear) tube 200ml	3	180	540
<b>Black board paint 1L</b>	<b>1</b>	<b>100</b>	<b>100</b>
Aluminum foil (for cooking) (*9m)	<b>4</b>	75	<b>300</b>
Grinding paper (1 square foot more or less)	1	20	20
Turpentine oil 0,5L (to wash paint)	1	60	60
Small rivets (repeat) bags	2	40	80
Electric scotch tape	10	10	100
Plastic string 15m	1	50	50
Iron wire 0,5kg	1	50	50
Threading tape (PTFE, Teflon)	10	10	100
Fevicol 0,5L	1	155	155
Metal collars	2	10	20
One dozen of nails of several sizes	1	20	20
Epoxy putting (in case of leaking)	2	45	90
		Total others	<b>1685</b>
		<b>TOTAL</b>	<b>24845</b>
<b>Iron Structure</b>			
Iron + welding to hold one panel	<b>2</b>	1000	<b>2000</b>
Iron + welding to hold the water tank	1	<b>1900</b>	<b>1900</b>
Metal primer 500mL	1	100	100
		Total iron struc- ture :	<b>4000</b>

## Example of standing structures

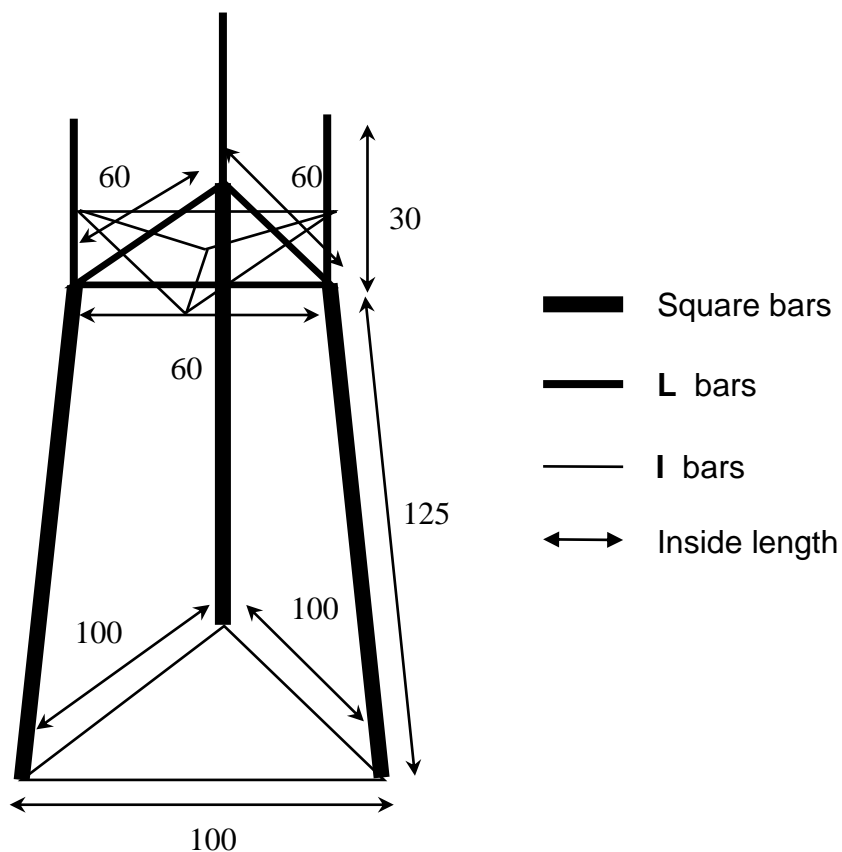
These iron stands are made to hold the hot water tank and the solar panel.

The following panel stand has an inclination of  $30^\circ$ , which is optimal for wintertime utilization in Nepal.



Be careful that the space between the two bars on the top of the structure is large enough to let the panel enter.

With an inclination of  $30^\circ$  and a panel of **2,10m**, you can calculate the height of your panel:  $2,10 \cdot \sin(30) = 2,10 \cdot 0,5 = 1,05\text{m}$ . So in this case, as you have to place your hot water tank **above the panel** (for the thermosiphon), a height of 1,20m for the structure should be good. You can now make your structure as below. The size of the horizontal standing part (60cm in this example) will change regarding to the diameter of your tank.



# Users Notes

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