SOLAR CONSTRUCTION MANUAL

by Radiantec Company

"What would you attempt do if you knew you could not fail" - Thoreau

This manual describes procedures for the installation of a solar heating system that can be used for simple thermal tasks such as:

1. **Domestic hot water,**
2. **Space heating with underfloor radiant heating tubes,**
3. **Snow melting,**
4. **Pool or hot tub heating,**
5. **And other moderate temperature applications.**

The sun will shine on one or more "solar collectors" which will collect the sun's energy and turn it into heat. The solar produced heat warms a solution of water and antifreeze, (hence, the term "hydronic heating system").

A simple control will turn on a pump whenever the temperature inside the solar collectors is warmer than the temperature at the place where the heat will be used. The antifreeze solution will then flow from the solar collector to a heat exchanger, (where the heat is put to use), and then back to the solar collector to be reheated.

This manual will describe the materials and construction methods used for the construction of a typical residential solar heating system.

Installation of a solar heating system from Radiantec Company is the work of a "reasonably competent handyman". He or she should have the skills to work with commonly available tools such as a hammer, saw, screwdriver, drill, tape measure, etc.

The basic skills of carpentry, pipefitting, roofing, and electrical work will be useful, but these skills need not be at a high technical level.

Only basic arithmetic and the ability to read a tape measure are required.

Prior experience with solar heating installation is not essential. The installation of a solar heating system is a series of sub steps. A person who has fitted copper tubing together, or who has wired a simple control, or who has attached something to the roof without a leak may find himself well qualified to do solar heating work even if he or she has never done it before.

Most building contractors or professional trades people will find that this is just another piece of work.

Our uses of words like "handy***man***", or "work***man***ship", or "he", or "she" does not imply any gender requirement. Worker attributes such as attention to detail, a willingness to read the manual, the selection and use of proper tools, and a commitment to quality work are far more important.

This manual provides ***general information***, but every project is a little different. The application of this general information to any specific project requires care, diligence and the consideration of all relevant factors. In particular, it is important to consult and comply with any applicable codes.

This manual may provide ***design assistance***, which is not to be confused with an actual design. A design is a professional service that considers all relevant factors. It would involve a plan review, a review of every applicable code, several site visits, a contract, and a fee. None of these elements are offered or compensated for in this "general information". Accordingly, the writer cannot assume liability for any consequences that might arise from the application of this general information or design assistance to any particular project. Also, the writer does not make any representation as to the completeness of the information offered.

The Radiantec Solar Construction Manual is offered in three parts:

1. **Construction of the Solar Loop. (This is where the solar energy is collected with solar collectors and delivered in the form of hot anti-freeze.)**
2. **Construction of the end-uses of the solar energy. (This is where the hot antifreeze is changed into something that we can use, such as domestic hot water, or heat for space heating, etc.**
3. **Appendices – This section offers a more detailed look at components, controls, and material choices etc., for those who want an in depth understanding about what makes up the solar heating system, and how everything works.**

A separate publication titled FUNDAMENTALS is offered which explores the nature of solar energy, collection devices, and energy storage methods.

SECTION 1

THE SOLAR LOOP

The "Solar Loop" is where solar energy is collected by solar collectors, turned into heat, and then pumped where it needs to go in order to fill our needs. It is a "closed" system consisting of solar collectors, a plumbing mechanical package and one or more heat exchangers. "Closed" means that the system has its own working fluid that stays in the system and is not removed except for maintenance.

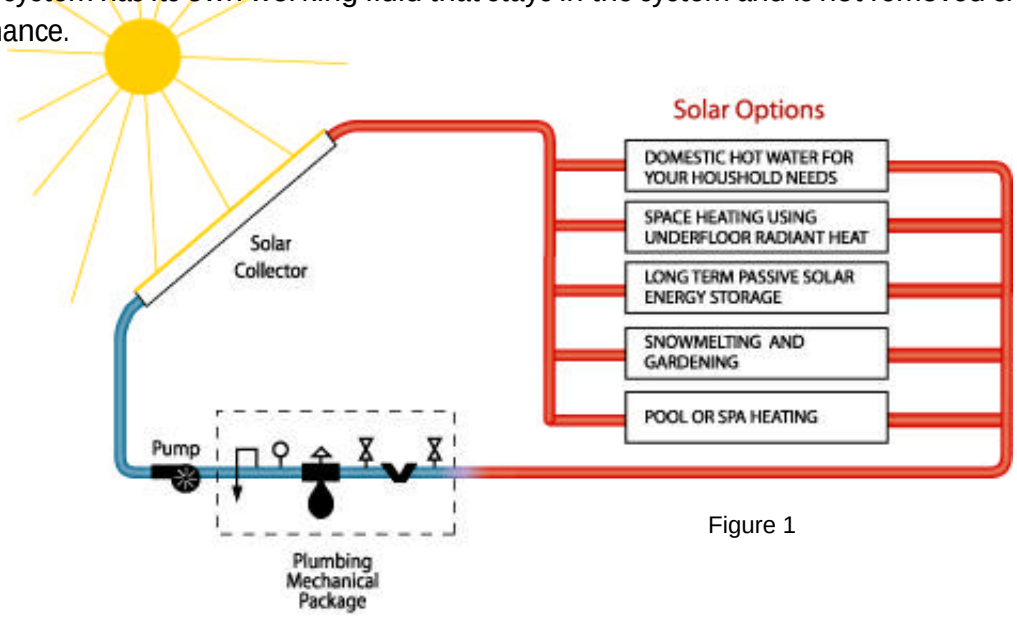


Figure 1

When the sun shines upon the solar collectors, the solar energy heats an antifreeze solution. When the solar heated antifreeze solution is warm enough, a circulating pump turns on and circulates the warm antifreeze solution to one or more heat exchangers, where the heat energy is put to a use such as the production of domestic hot water, or space heat, or some other use. The antifreeze solution then returns to the solar collectors to be reheated.

THE SOLAR COLLECTORS

The solar collector, as used in a Radiantec Solar Heating System, is a shallow aluminum box with a tempered glass cover sheet. Typical nominal dimensions are 4 ft x 8 ft x 4 in, although other sizes are available. The weight will be about 125 pounds. Several collectors are usually connected to each other so that they form one large solar collector array. The collectors have "internal headers" which go across the top and bottom and have outlets on the sides. When the collectors are connected, the headers of one solar collector are soldered to the headers of the other. A water based antifreeze solution flows into the bottom of the collector on one side and comes out the top on the other side after being heated by the sun

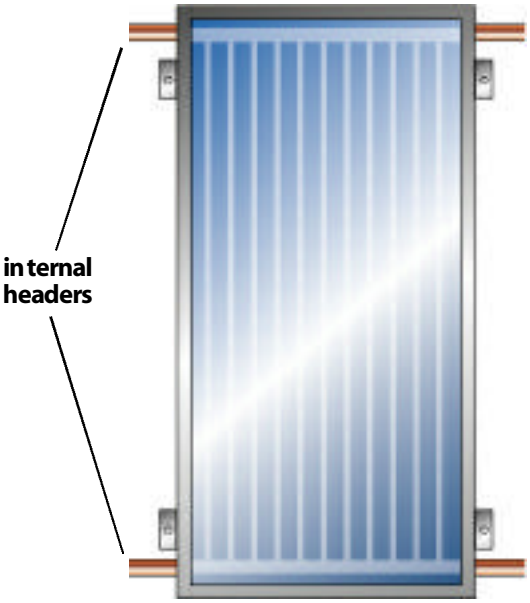


Figure 2

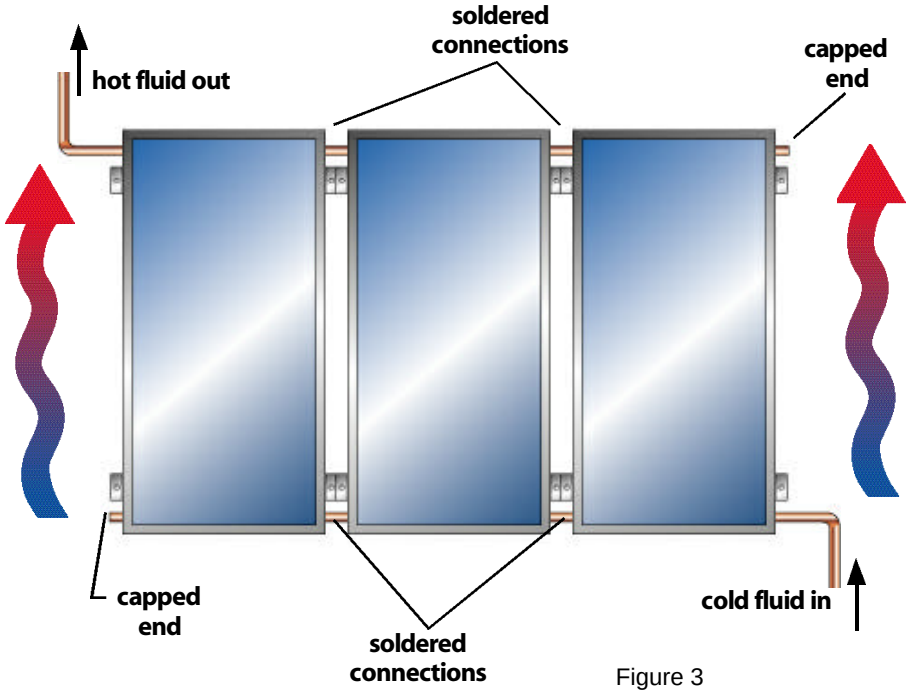


Figure 3

INSTALL THE SOLAR PANELS

PLEASE CONSIDER THE FOLLOWING SAFETY RECOMMENDATIONS

1. **Hard hats -** The worksite is a hard hat area while work is being done on the roof. There are a number of hazards, and tools or other materials could be dropped accidentally. Rope off the area beneath the roof and consider posting a sign saying that the area is a hard hat area. Keep onlookers at a safe distance.

2. Do not work underneath an unsecured solar panel.

3. Solar panels get hot when bright sunlight is shining upon them and nothing is taking away the heat. Wear gloves. Avoid working with solar panels in the middle of the day. Cover the panels with part of the shipping carton or with a sheet.

4. Wear sunglasses when working with solar panels on sunny days. The glare reflecting from solar panels in bright light is very uncomfortable and distracting to the point of causing a safety problem. Workmen who do not wear sunglasses are likely go home early with a headache.

5. Consider using a crane. It might be safer to use a crane for mounting the solar panels and it is less expensive in the long run because of lowered labor costs. A crane could mount all solar panels for a typical residence in less than one hour. It can be economical to rent a crane and operator from a local sign contractor. Use of a crane allows workmen to stay off of the roofing material.

6. Erect a proper and safe scaffold. It is safer and will save many trips up and down the ladder.

7. Use a proper tool belt. It will also save many trips up and down the ladder. A tool belt will leave your hands free to hold onto the ladder. Do not carry any extra tools. If you drop a screwdriver with a tempered bit onto a solar collector with tempered glass, the glass could break immediately, or it could break up to a week later.

8. Never, ever work with untemperd glass on the roof.

PLAN THE LOCATION OF THE SOLAR PANELS

1. Plan and locate the position of the panels with chalk lines so that their appearance can be visualized. Solar panels are generally more attractive if they are placed at or below the midline of the roof area.

2. The customer should approve the location of the panels before the work begins. Take a sheet of plywood up to the roof if it will help to visualize the finished work.

3. Keep in mind that work will have to be done behind the roof to prepare a solid support for the solar collector legs. Do not put the collectors in a place where this work is inaccessible.

4. Coordinate with the General Contractor. Make sure that the General understands that solar panels will be placed upon the roof and that the roof must be built to the proper dimensions. Building insulation should not be installed in the solar work area until the solar work is roughed in and pressure tested.

5. Snap another chalk line in the place where holes will be drilled for the collector mounts. Hold the line tight enough that it does not dip in the middle.

6. Start in the middle of the roof and work outward. That way, you can be sure that the work will be centered on the roof.

7. Measure twice before drilling holes in important locations.

8. Foresee everything that needs to be done before starting work. Read the entire manual before starting. In particular, note the following:

a. Blocking should be installed behind the solar panels in new construction.

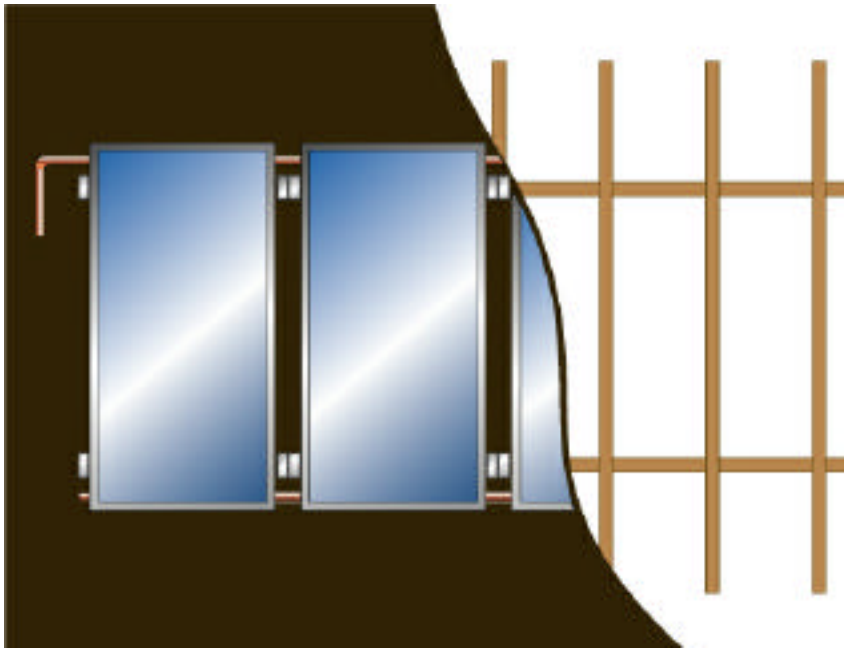


Figure 4

b. For even flow, the solar fluid will flow into one side of the solar array at the bottom, and come out on the other side at the top (called reverse return). The "C" type fluid return where the fluid comes out on the same side of the collector array that it went in is only acceptable for no more than three solar collectors. Be sure that there is a good way to run and insulate these supply and return pipes

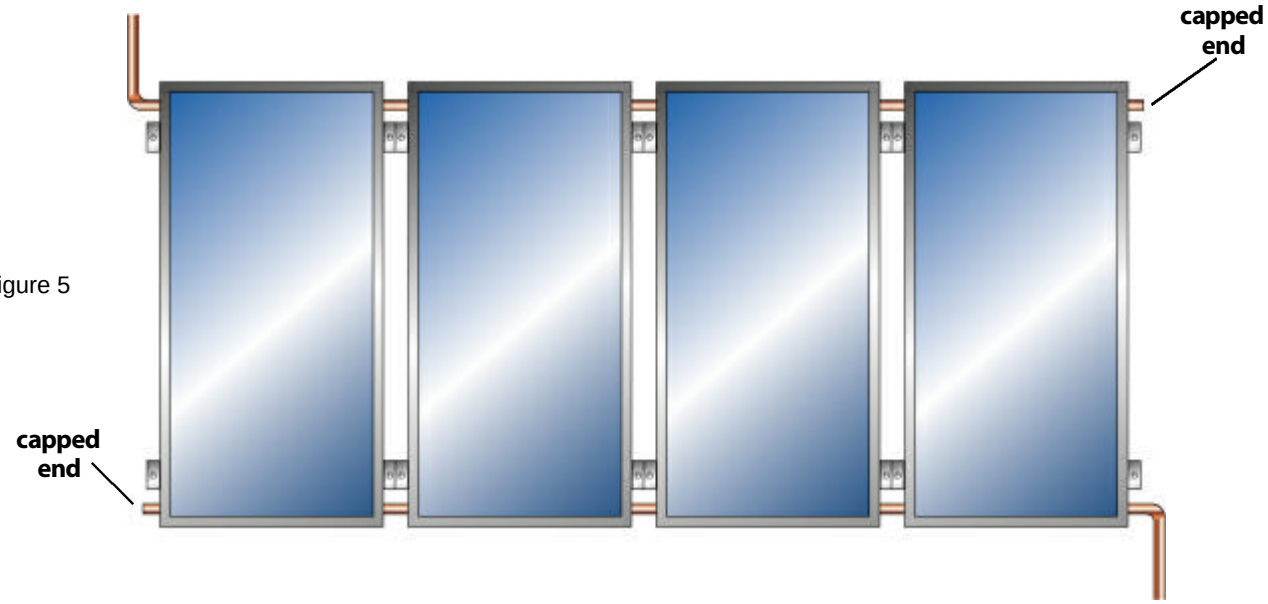


Figure 5

c. Two temperature sensors will be located at the outlet of the solar array. Two sets of wires, (18g thermostat wire, two wire), must be run from the outlet to the mechanical room before the work is closed up.

d. Plan for expansion and contraction of the header pipes within the solar panel. Solar collector temperatures could vary between the coldest expected outdoor temperature, and the stagnation temperature of the collector in full sun. This temperature difference could be up to 300 degrees F. The detail shown in figure #6 is adequate up to eight 4'x8'solar panels in a row.

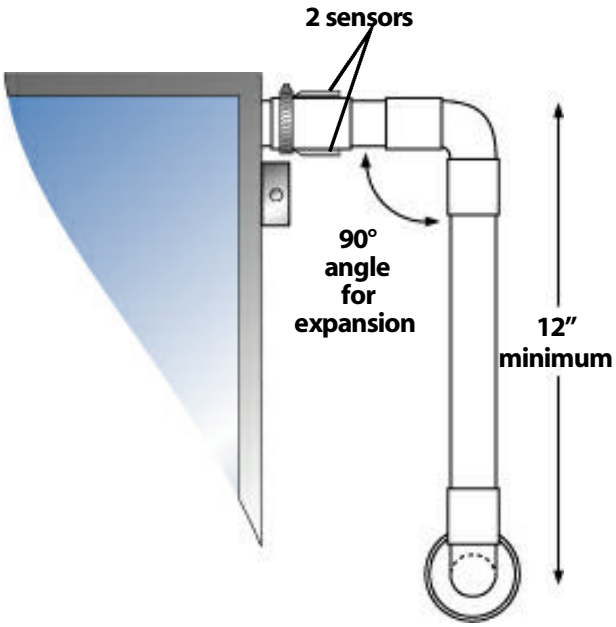


Figure 6

INSTALL THE BLOCKING BEHIND THE ROOF

1. Blocking transmits the solar collector loads to the rafters and provides something solid to screw the lag bolts into. Do not just lag the solar panels to the plywood sheathing; it is not acceptable. If blocking can not be installed (as in a retrofit situation), the lag bolts must be drilled directly into the rafters, or something else solid. Mounts provided by Radiantec can slide along the top and bottom edges of the solar collector so that mounts can be installed directly into the rafters.

2. Blocking should be installed whenever possible because the collector array will be more attractive if the mounts are spaced evenly and the rafters can be difficult to locate exactly.

3. The blocking should be close fitting and square. They may be 2"x 4"or 2"x 6", and they can be installed with the flat side up (towards the plywood). It will be easier to hit them squarely, and they will be just as strong. They must be securely nailed with 16d nails or better.

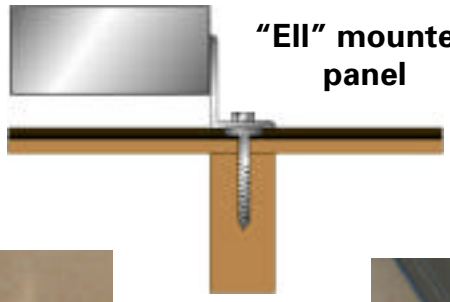
PREPARE THE PANELS FOR MOUNTING

1. Attach the mounts to the panel. It is important to avoid the use of different kinds of metals when fastening to the solar collectors. When different kinds of metals are used, the metal that is more stable will corrode the metal that is less stable. Use stainless steel fasteners that are especially resistant to corrosion, or use materials that are all made of the same material. Rubber from an inner tube or roofing material could insulate one material from another, but it is not a real good detail, and it won't help at all in a moisture situation. Better to avoid the problem in the first place.

2. Mounting kits supplied by the Radiantec Company will be compatible with the solar collectors.

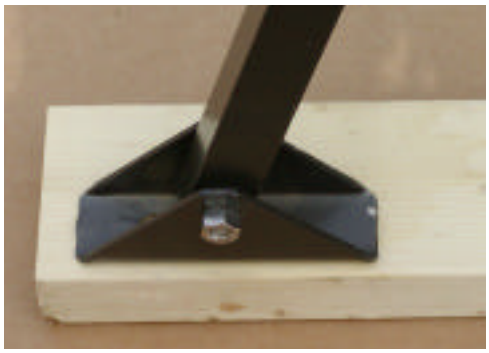
3. Attach the mounts so that the solar panels are held about 1"off the roof in order to prevent moisture from damaging the roofing materials.

SOLAR COLLECTOR MOUNTS



"Ell" mounted panel

Mounted at angle



Angle mount

Plumbing connections must be made (using 1" copper couplings) at the time that they are mounted. The pipe ends are prepared, cleaned, fluxed and fitted with a coupling on the ground. Check all pipe ends on the ground to be sure that the couplings fit properly. Take care when bringing the panels to the roof that the pipe ends are not dented out of shape. If you temporarily place a fitting on the pipe end it will be less likely to get damaged.

BRING THE SOLAR PANELS TO THE ROOF AND SECURE THEM

With planning and proper equipment, it is possible to do this work without stepping on the roof.

It is best to build a secure scaffold. If a sign crane is used, consider making a sling out of wire cable and cable clamps, even if it is only used once. The materials are cheap and a proper sling will save a lot of time and aggravation on the job. If you use a heavy rope, it will be difficult to retrieve from behind the solar panel. If you use a lighter rope, sharp metal edges may cause it to fail at a bad time. If it is windy, use anchor lines on either side of the collectors.

When the panel arrives at the roof, the workman first assembles what plumbing connections need to be made. He does not solder the connections at this time. He will drill a pilot hole for the mount with reference to the earlier made chalk line.

He may then insert a screwdriver through the hole in the mount and then into the pilot hole. This will temporarily secure the panel in place and prevent the plumbing connection from becoming undone.

When he is ready, the workman will apply a silicone-based sealant to the pilot hole and put a lag bolt in, but not tighten it all the way. When the lag bolts are inserted, the silicone sealant will be squeezed under the pressure and fill any cracks or voids that water might leak.

Only when the lag bolts are in the bottom mounts is it safe to undo the sling from the crane and the solar panel.

It may be necessary to lift the solar panels a little bit in order to retrieve the sling or to make the plumbing connection. Tighten the lag bolts completely when this work is done.

Do not choose the drill bit for the pilot hole haphazardly. This detail is important for both structural strength and water tightness. Guess at the size and then drill a pilot hole in a piece of scrap wood. Drive a lag bolt in. If you hear cracking noises and the bolt seems to be splitting the wood, the pilot hole is too small. If the bolt goes in very easily and strips easily, the pilot hole is too large. Each workman should drive a lag bolt into a piece of scrap wood until it strips the hole. Then he will know how much force can be applied to the bolt. The attachment will be both strong and watertight if made properly, and might be something less if it is not.

The copper connections, top and bottom, may be done at this time, or they can all be done at the same time if the work will not be delayed too long (not overnight).

Solder the connections using standard, no lead solder. Do not use 95/5, or silver solder and do not braise it. It is not necessary and the excess heat will damage seals and insulation within the panel. The person who does this work should be good at it.

If high quality solar collectors are used with tempered glass, it is possible to set a ladder directly on the collectors.

Insert the lag bolts for the mounts at the top of the collectors and pressure test the work at this time.

Pressure test your work as you go. That way, if you have a problem, you will know that the problem is with the last thing that you did, and it will be much easier to find.

INSTALL THE PLUMBING MECHANICAL PACKAGE

The plumbing mechanical package is the place where all mechanicals and components are centered. It should be located in a mechanical room that is separate from living quarters. This separation will lower the perception of pumping noise (which will be nearly negligible) and eliminate nuisance heat production during the cooling season.

The PMP will contain what is needed for the proper functioning of a closed loop, hydronic heating system and will be similar in function to what a boiler system might contain, but there are important differences.

The PMP will contain at a minimum, fill and drain valves, isolation valves, an air eliminator, an expansion tank, a pressure relief valve, a pump, and a one-way check valve. Details about these components are provided in the appendix .

When the construction of the solar loop is complete, there should be a way to:

1. **Fill the system**
2. **Drain the system (with little or no mess)**
3. **Flush the system**
4. **Back flush the system**
5. **Get all of the air out, and keep it out.**
6. **Work on anything mechanical without draining the system**
7. **Prevent reverse thermo siphoning at night**
8. **Read the system pressure**
9. **Relieve expansion and contraction of the working fluid**
10. **Mount the pump**
11. **Relieve pressure on the solar panels under unforeseen conditions.**

We strongly recommend the use of an installation package that is pre-assembled, pre-engineered, and pre-tested. The right components are assembled using the right tools by skilled technicians in the shop under ideal conditions, and then fully tested.

The planned arrangement helps produce an attractive and professional looking job.

The pump, expansion tank and other components are sized and selected for proper flow and performance.

The plumbing work must be careful and professional for several reasons.

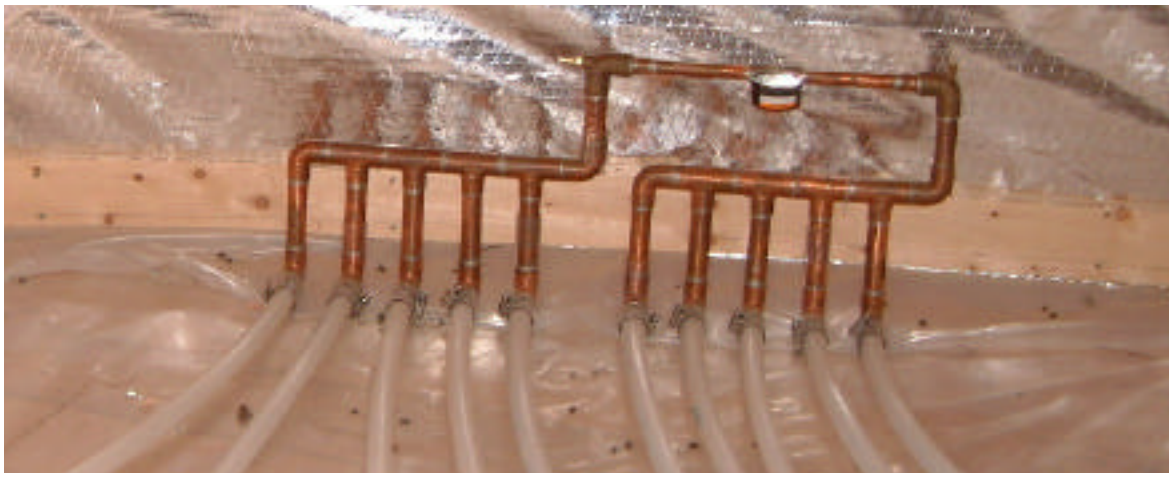
1. **An anti-freeze solution is more viscous than water, and it will leak in places where water will not.**

2. **A small leak will not repair itself by corrosion.**

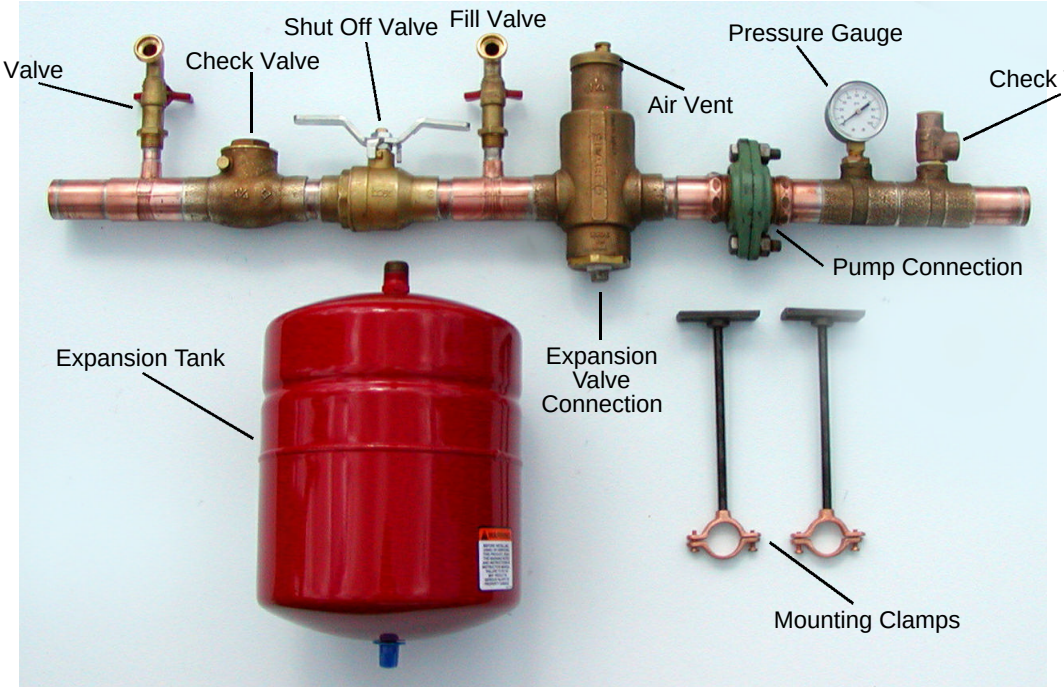
3. **A water makeup valve is not appropriate because it would dilute the antifreeze solution without notice and subject the system to expensive freezing damage.**

Threaded fittings are to be avoided whenever possible. They are much more likely to leak than a good soldered joint. When a threaded fitting cannot be avoided, "mate" the fittings by threading them together and taking them apart several times. This procedure will machine the two fittings so that they fit together perfectly and clear the threads of burrs.

The components of the PMP are put together in the proper ***arrangement***, and that is quite important. Of particular importance is the location of the pressure relief valve. ***There must be no valve, or combination of valves which if closed would isolate the pressure relief valve from the solar panels***. Failure to obey this fundamental rule of plumbing could cause expensive damage to the panels or to a heat exchanger and could even cause a safety problem. Do not add extraneous valves to the system without making sure that they will not cause problems.



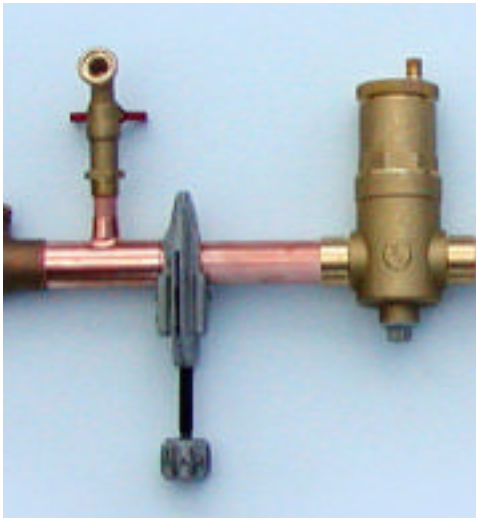
The plumbing mechanical package as it comes out of the crate.



The PMP must address each of these issues. If the Solar Loop needs attention in the future, it will probably be at the PMP because this is where any moving parts and threaded fittings are. Isolation valves should be used so that work can be done on the PMP without draining the whole system. (But do not isolate the pressure relief valve.)

If the PMP is purchased whole, the installer simply takes the PMP out of the crate, cuts it where indicated and screws it to the wall or hangs it from the ceiling.

Cut the tubing where indicated and attach elbow fittings.



Attach the PMP to the wall or hang from the ceiling.

The pump and expansion tank are then added to the package. Do not pressure test the system with the expansion tank in place as it may be damaged. Keep the 1/2" iron plug beneath the air eliminator in place for pressure testing and then remove it to install the expansion tank.

Add warning labels to the fill and drain valves, plumb pressure relief valve to a safe place. The warning label should say:

DANGER – DO NOT OPEN THIS VALVE.
THE PIPES DO NOT CONTAIN WATER.
THE SYSTEM CONTAINS AN ANTIFREEZE SOLUTION AND MIGHT BE VERY HOT!!

Locate these valves high and out of the reach of children. Limit access to this mechanical area to adults. Secure this area as you would a boiler.

HEAT EXCHANGERS

Heat exchangers will be added to the solar loop according to instructions given in the "END USES" section. The purpose of these heat exchangers is to exchange the heat that is in the hot antifreeze solution to something that is more useful, such as domestic hot water.

RUN THE TUBING BETWEEN THE SOLAR PANELS AND THE PLUMBING MECHANICAL PACKAGE

Penetrate the roof with the following detail. This work should be quiet, efficient and permanent.

Roof Penetration Detail

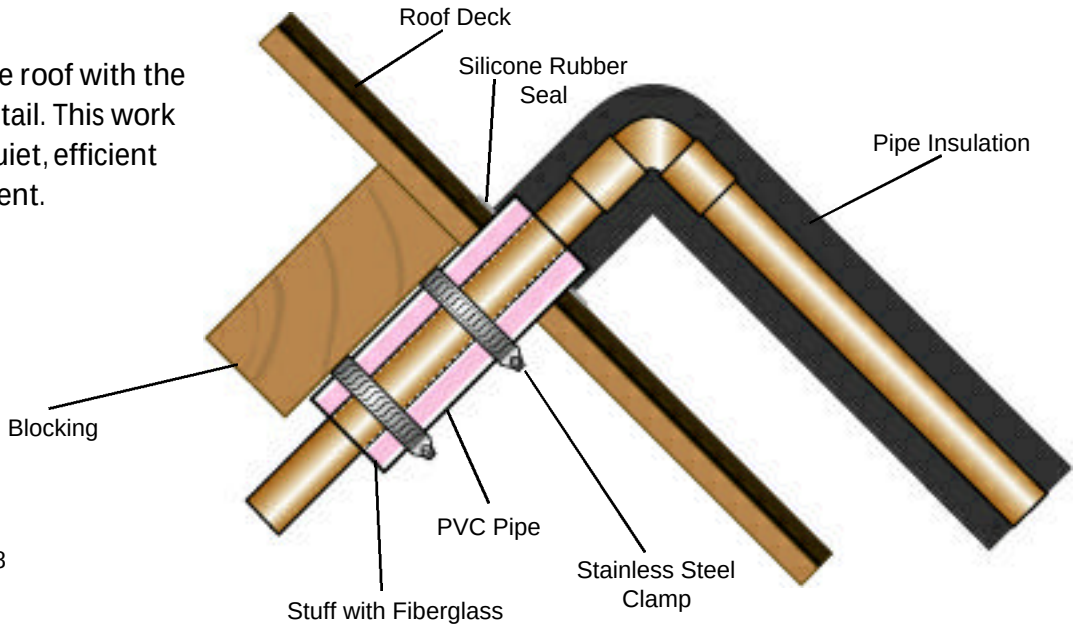


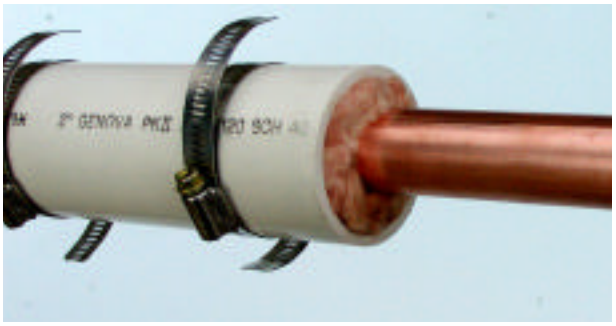
Figure 8

It will be quiet and efficient if the tubing is insulated first, and then fastened securely to the framework of the house.

Find a 8-10 inch piece of 2" PVC or ABS. Run the tubing in the middle and cram Fiberglass all around it. Compact until quite tight. Then secure the PVC firmly to a framing member with two stainless steel clamps and screws or nails. Seal with silicone sealant, top and bottom and sides.

Whenever possible slant the tubing so that it can drain completely.

Use the same detail to support tubing on long runs within the building.



Plan to avoid overheating at plastic fittings. The solar loop can get quite hot when it is making domestic hot water. Make sure that heat cannot conduct to plastic fittings or anything that cannot tolerate high heat. Hot water will rise by gravity (thermo siphon) up a vertical length of pipe. Copper pipe is very conductive and can conduct high temperatures downward. A two foot length of un-insulated pipe in a downward direction is often adequate to dissipate enough heat to protect plastic fittings. If in doubt, verify with temperature measurements, and take additional precautions.

Insulate the solar loop for efficiency, safety and avoidance of nuisance heat during the summer.

Do not forget the temperature sensor wires.

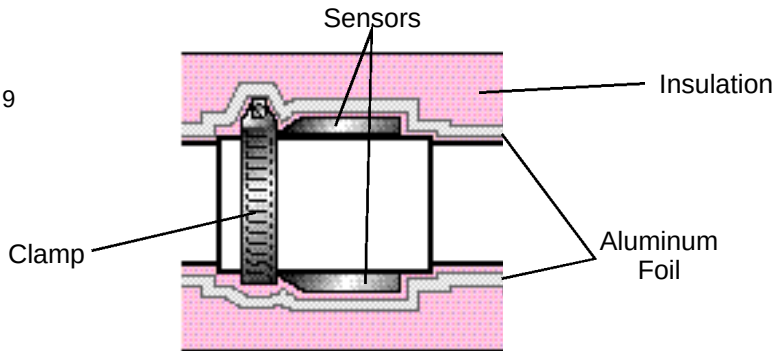
Attach heat exchangers to the solar loop per individual instructions in the following chapters to transfer heat to various uses such as domestic hot water or radiant underfloor space heating.

CONTROLS

A "differential temperature control" will turn on the pump whenever solar heat is available to be harvested, and turn the pump off whenever solar heat is no longer available. The electronic control works by comparing the temperature at the solar collector sensor with the temperature at the storage sensor. If the solar sensor is warmer than the storage sensor by a certain amount, the pump will turn on.

It is quite important that the sensors be properly installed in the proper place, or solar perform-

Figure 9



ance will be compromised by 15% or more.

At the solar collector, the sensor should be strapped on with a stainless steel clamp, and then wrapped with aluminum foil so that the sensor works as if it were part of the pipe itself. Then insulate the sensor carefully as well as the rest of the pipe, so that the sensor cannot sense air temperature instead. Do not use an immersion type sensor; it will not be more accurate, and it will be a threaded fitting. It will also be more difficult to insulate. If you have an electrical problem, you will then have a plumbing problem as well.

The storage sensor may be located in the storage if there is only one application for the solar energy. If there are multiple uses for the solar energy, the sensor may be attached to the solar loop pipe returning from the last heat exchanger. Again, the sensor should be wrapped with aluminum foil, which is then wrapped around the pipe. The sensor will closely read the temperature of the pipe, which closely tracks that temperature of the fluid within.

A detailed discussion of solar control logic is provided in the appendix.

Use wire nuts and protect from moisture with silicone rubber sealant.

Locate electrical components away from plumbing components.

Use the attached solar control schematic to wire the control and use the following settings.

FILL THE SOLAR LOOP WITH FLUID

WARNING !!! Do not do this work in strong sunlight unless the solar collectors are covered!!! If you feed water to a stagnating solar collector, the water can flash to steam and cause considerable damage to the collectors and even present a safety hazard. Serious burns and even death could result.

With that warning noted, attach a garden hose to the fill valve of the Plumbing Mechanical Package (PMP). To make the connection, you will need to find or make a short length of hose with two female ends on it (a washing machine hose is ideal).

Then, attach one end of another length of garden hose to the drain valve, and take the other end outside to an appropriate place.

Close the ball valve between the fill and drain valve so that the water is forced through the whole system. Close the air vent in the PMP so that it will not function (it could become plugged up).

Flush the system thoroughly with water to get out any flux, solder, air, dirt, and anything else that is not wanted in the system.

Then close the drain valve and allow the system to pressurize. You can open the air vent after the system has been flushed.

Get the system running well with water. Fix any leaks before you add antifreeze.

Then add a predetermined amount of pure anti freeze based upon a calculation of the total amount of fluid in the system

EXAMPLE: If you want the final solution to be 30% antifreeze, and the system calculates to be 60 gallons total, add 19 gallons of pure antifreeze and take out 18 gallons of water, and you will have it.

Let the system run for a while and then test with a hydrometer or test strip to make sure of the concentration.

Consult the appendix to find typical amounts of fluid per linear ft of tubing and typical fluid capacity for Radiantec solar collectors, so that you can calculate total fluid volume.

PIPE INSULATION

Insulate all tubes for safety and efficiency. Insulation should have at least 1/2" wall thickness. In particular, be sure that any sensors are well insulated. Be sure that any exterior pipe insulation is resistant to UV radiation and moisture.

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