Disclaimer
This manual is a source of information only, we take no responsibility for omissions, incomplete or misleading (safety) information. It is the legal duty of the contractor make sure that they are competent to carry out this type of potentially hazardous work. It is also assumed that a competent plumber will carry out this work.

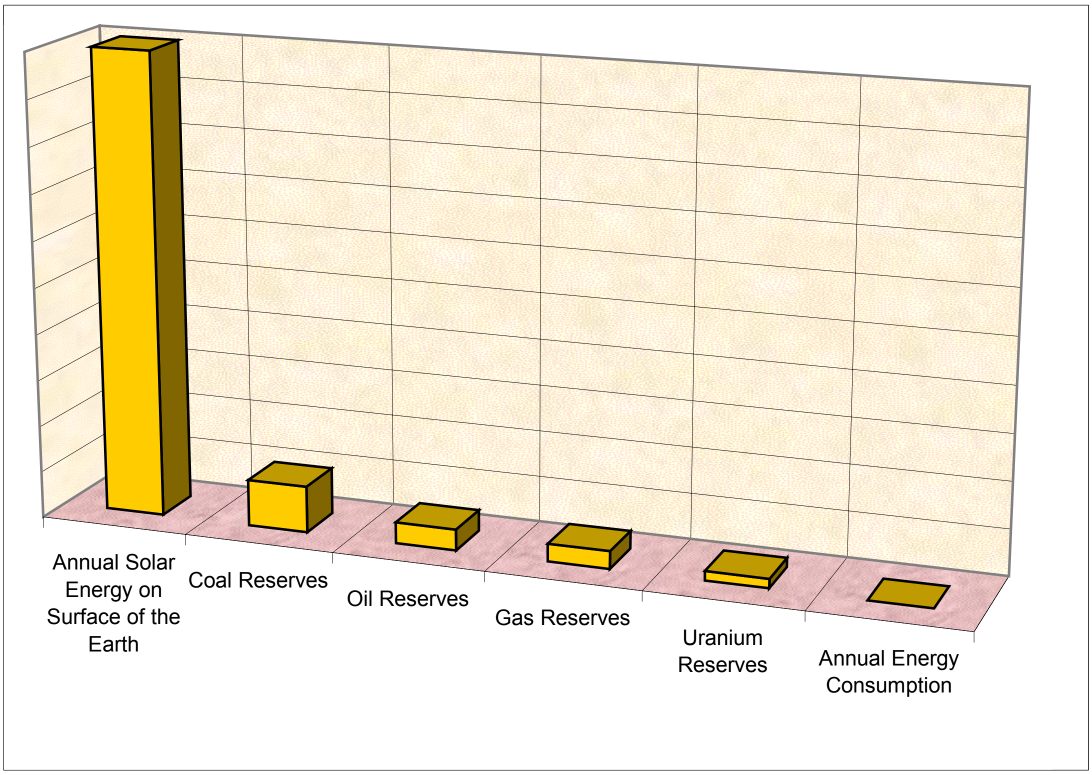
This complete manual should be studied and understood before the installation. There are quite a few tips and tricks that we have picked up installing ourselves that save hours of grief later on.

Solar facts and figures

The sun provides more than 10,000 times the energy needed by the human race.

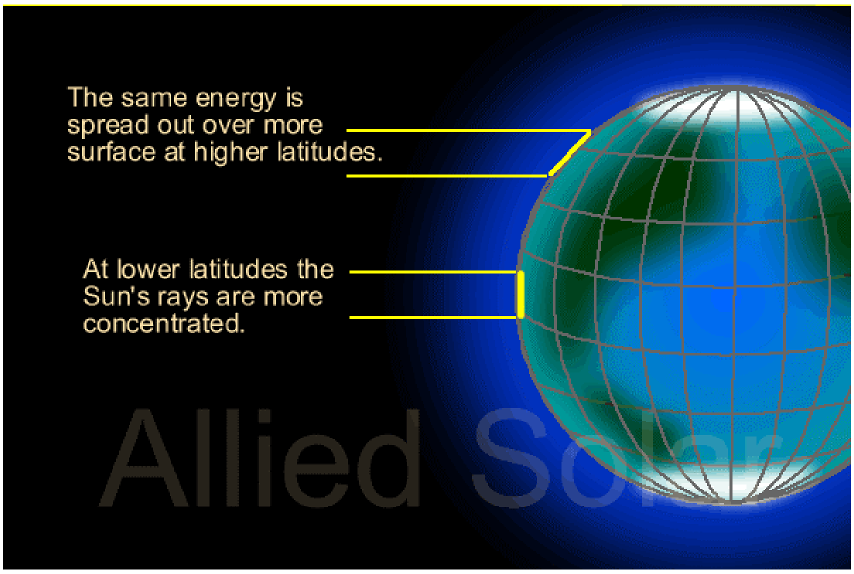
Almost all energy ultimately comes from the sun. Coal, Oil, Gas and peat are fossil fuels. These are the remains of plants which captured energy over millions of years from the sun.

The graph shows the amount of energy generated by the sun each year. As you can see, the annual worldwide energy consumption is just a tiny tiny fraction in comparison to the solar energy incident on the earth.



A 40 sq meter roof in Ireland will typically receive in excess of 37,000 kWhrs annually.

Insolation Levels



Insolation means the amount of energy reaching the earths surface per square meter. (KW/M2) The largest radiation values are over the equatorial zone because the Sun's rays are more concentrated.

Towards the poles the rays hit the Earth's surface more obliquely and are more diffuse and therefore have lower radiation values.

From the diagram above, it can be seen that for a given segment of insolation, the area that is covered in the tropics is much smaller than at the poles. In other words, the same amount of energy that hits the Earth's surface at the poles is much weaker and more dissipated than at the equator. The amount of air clouds & dust that the radiation has to pass through is greater the further you move away from the equator. This will result in more of the insolation being reflected by the atmosphere (due to cloud cover, particulate matter in the atmosphere etc.) at the poles. Because the northern hemisphere tilts away from the sun in winter, and tilts towards the sun in summer, this effect changes between summer and winter.

How big is this effect?
On a cloudless day, directly facing the sun at mid day, mid winter insolation levels are about ½ of summer levels. However because the sun is low in the sky, the available energy is spread over more ground, so each sq meter of ground receives much lower energy in the winter.

Nasa Website
http://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?uid=3030

Met Eireann
http://www.weather.ie/climate/monthly-data.asp

What units are used to express Insolation levels?

The values are generally expressed in kWh/m2/day. This is the amount of solar energy that strikes a square metre of the earth's surface in a single day. Of course this value is averaged to account for differences in the days' length. There are several units that are used throughout the world.

The conversions based on surface area as follows:
1 kWh/m2/day = 317.1 btu/ft2/day = 3.6MJ/m2/day

The raw energy conversions are:
1kWh = 3412 Btu = 3.6MJ = 859.8kcal

Is Ireland's insolation level low, moderate or high?
The following scale is a basic guide for insolation levels. Although a value of 5 is not considered very high during the summer months, as an average annual value this is very high. You will see that in central Australia, which is a hot, sunny place, the annual average insolation is 5.89.

Average annual insolation levels:
Central Australia = 5.89 kWh/m2/day - Very High
Dublin, Ireland = 2.56 kWh/m2/day – Moderate

Direct and Diffuse Radiation
By angling the solar panel towards the sun, the solar panel can take advantage of the “extra” direct solar radiation equivalent to the size of the shadow of the panel. Angling the panel however does not cause any significant increase from diffuse radiation.

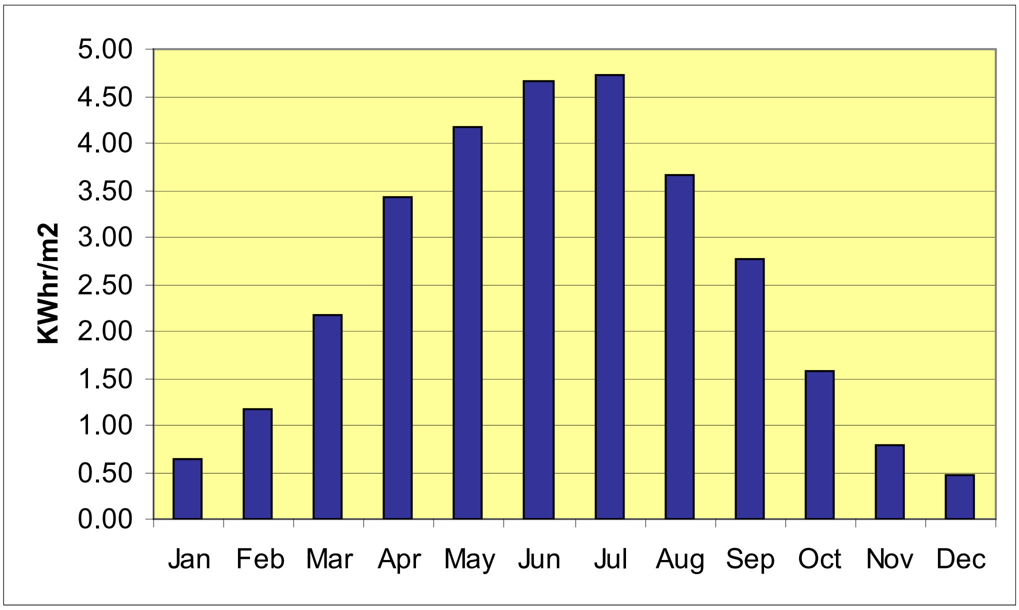
Diffuse radiation is caused by deflecting direct radiation;

- Air molecules – (Rayleigh scattering)
- Dust Particles – (Mie scattering)
- Cloud Cover

Over many years the average proportion of diffuse to direct radiance has been found to be between 50% and 60%, with much higher values in the winter. The following graph and table gives the average daily Global radiation KWhr/m2 (Diffuse + Direct) measured in Dublin Airport.

As can be seen there is about 10 times more solar energy in summer than winter, this is one of the factors that makes designing solar heating systems challenging!

KWhr/m^2/day measured at Dublin Airport.



Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.65	1.18	2.18	3.42	4.17	4.65	4.73	3.66	2.76	1.57	0.78	0.46

Panel outputs at different panel angles

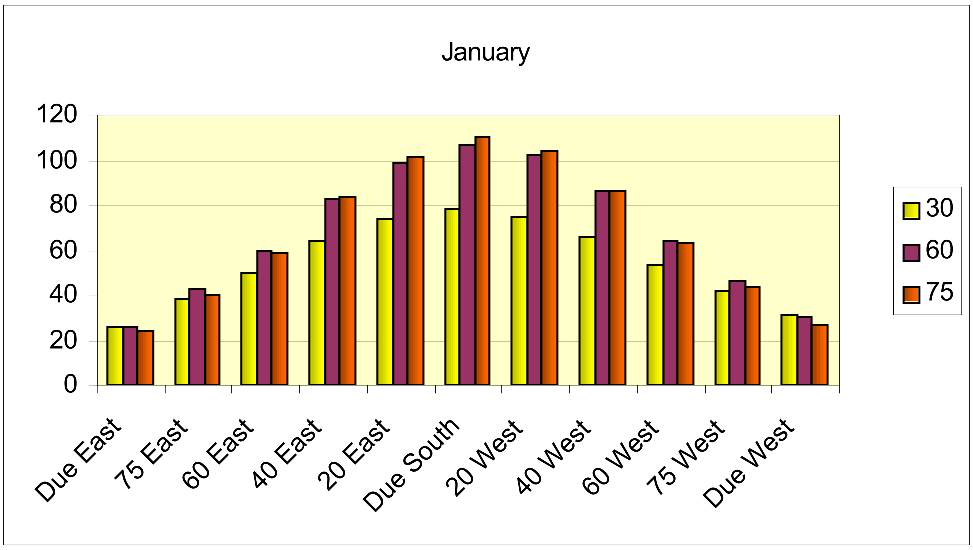
Despite the massive differences between summer and winter energy levels, a significant correction can be made by the angling of the panel so that equivalent winter shadow lengths are as long as possible. The solar panel is then receiving all the energy in the shadow area.

The graphs below show the expected monthly outputs of a 6 sq meter flat plate panel connect to a 300 litre cylinder. These results were obtained using the T*Sol solar simulator. (more information can be found on www.tsol.de)

A Steeper roof angle gives substantially more output in the winter, and less in the summer. It can also be seen from the graphs that there is a western bais, showing that given a choice of 2 roofs, a West facing roof is preferable to an Eastern facing one.

Generally a flat plate will output about 350KWhrs annually for each square meter installed up to about 6 meters squared. Diminishing Returns are apparent for larger sizes.

It is also recommended that a minimum 50 litres of hot water storage is available for each square meter of panel.


January
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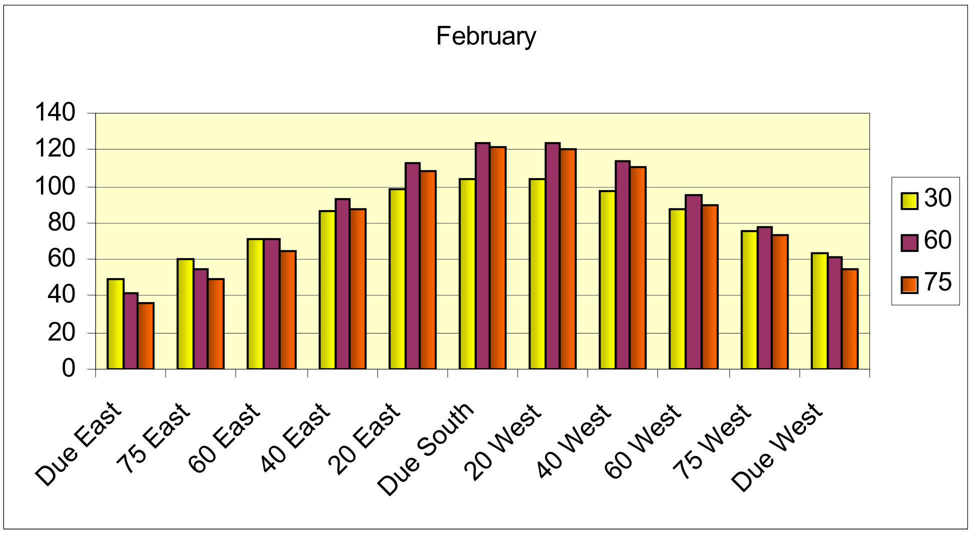
February
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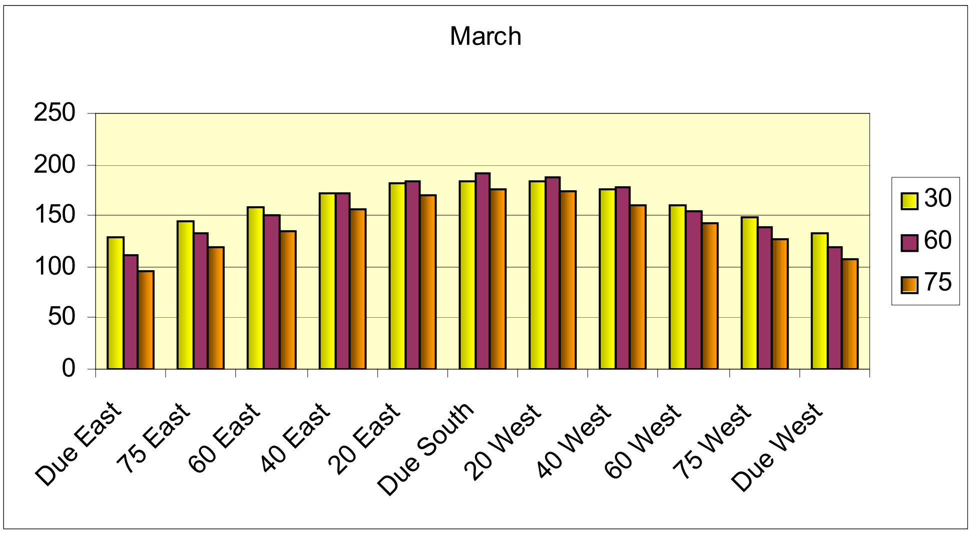
March
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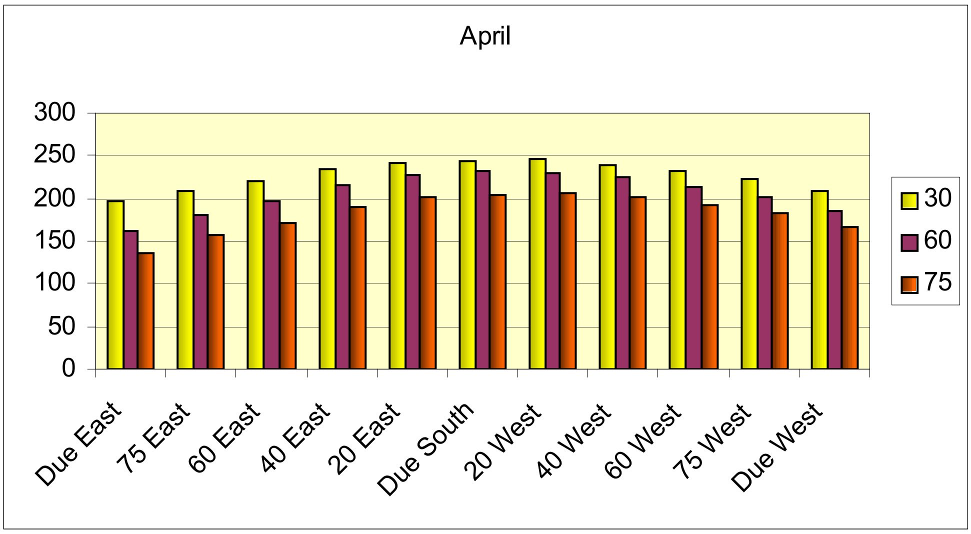
April
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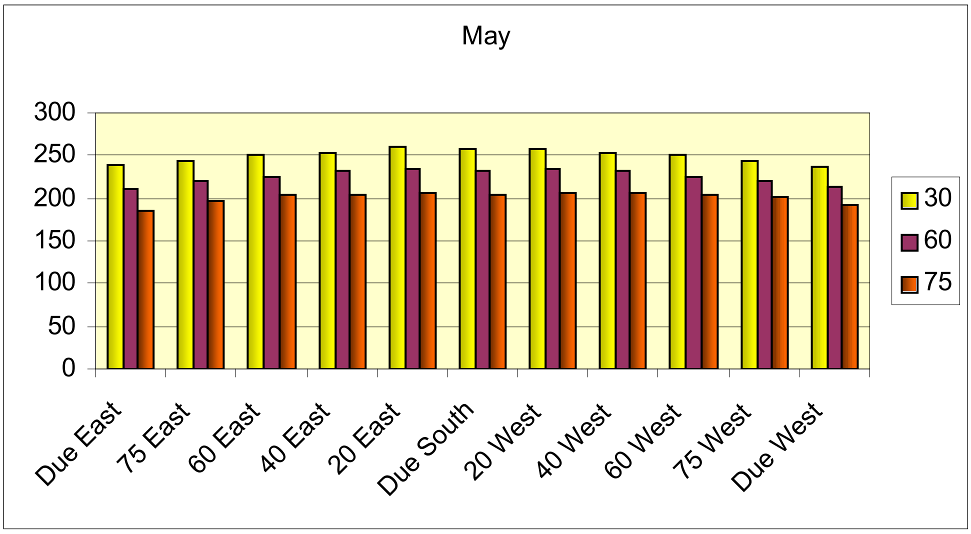
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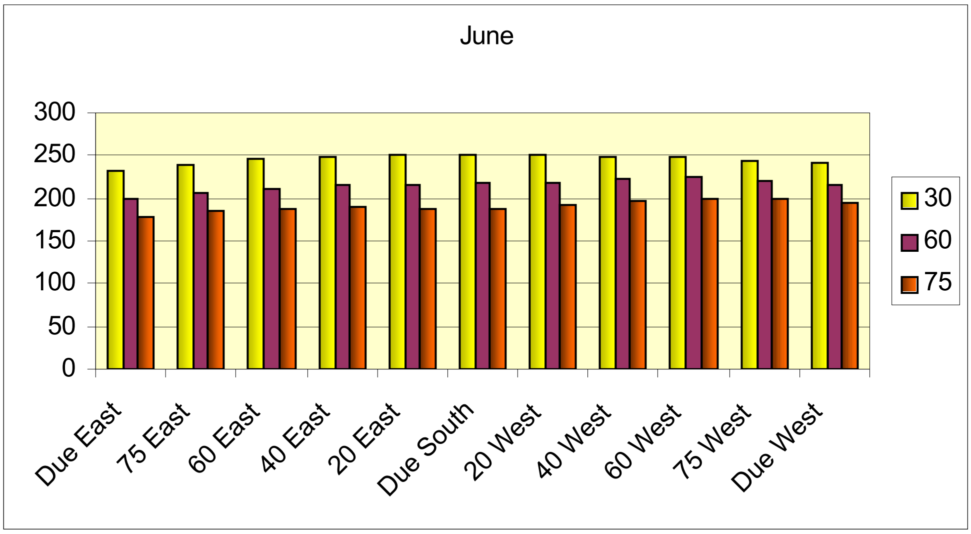
June
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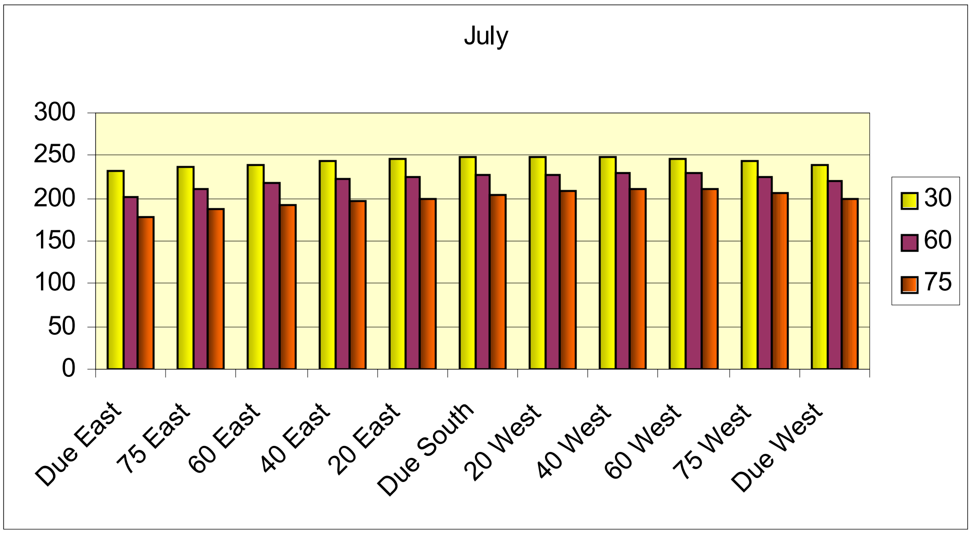
July
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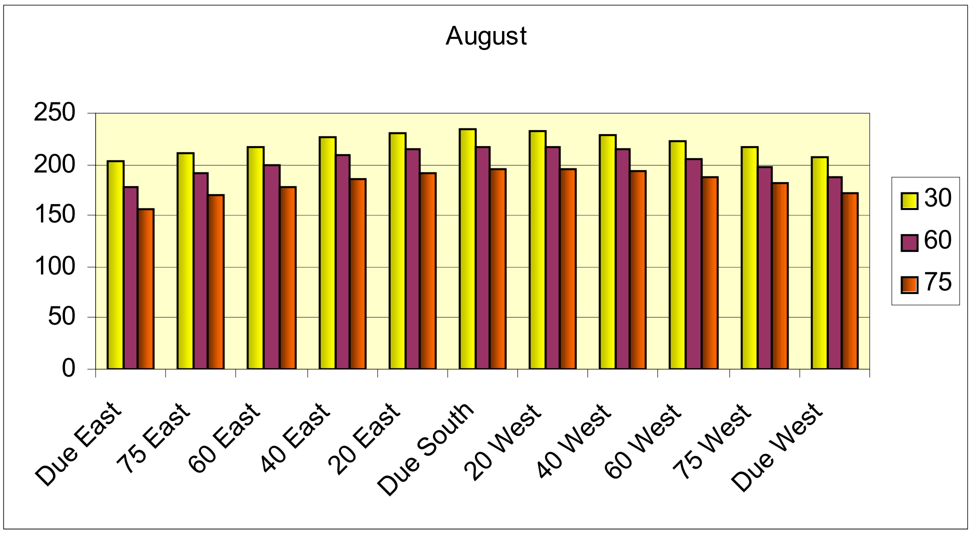
August
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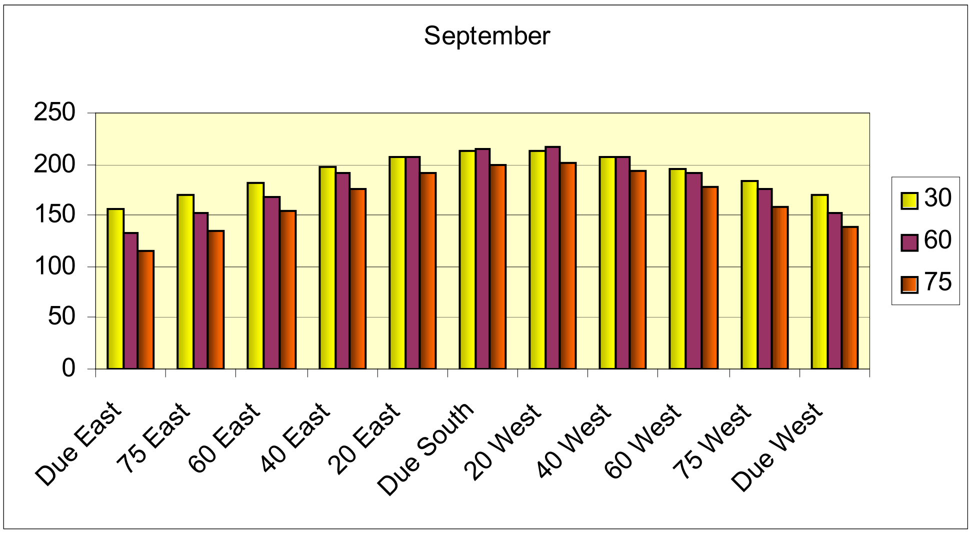
September
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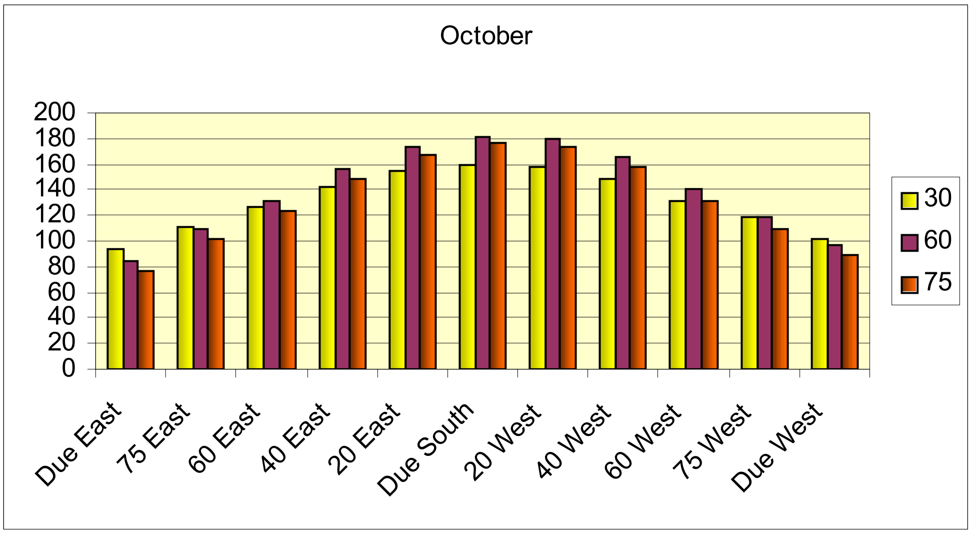
October
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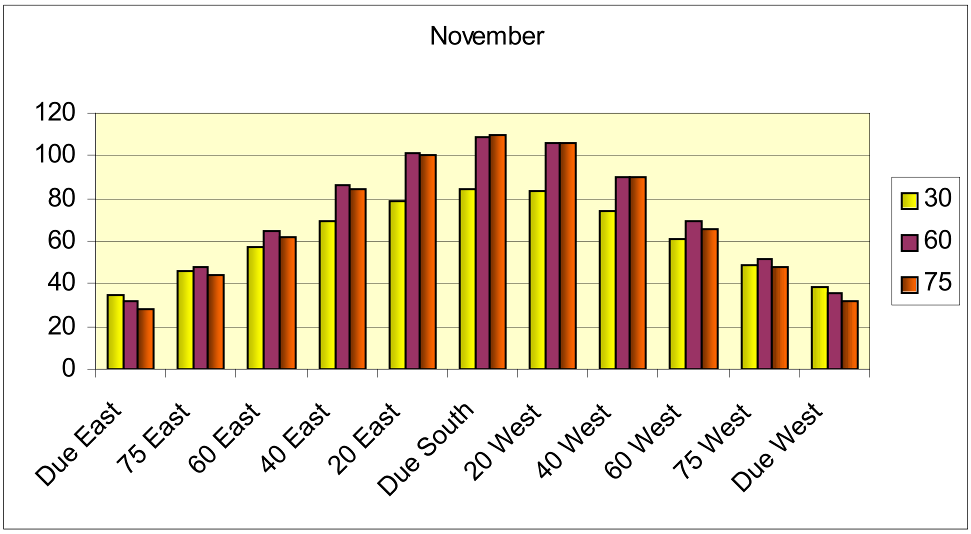
November
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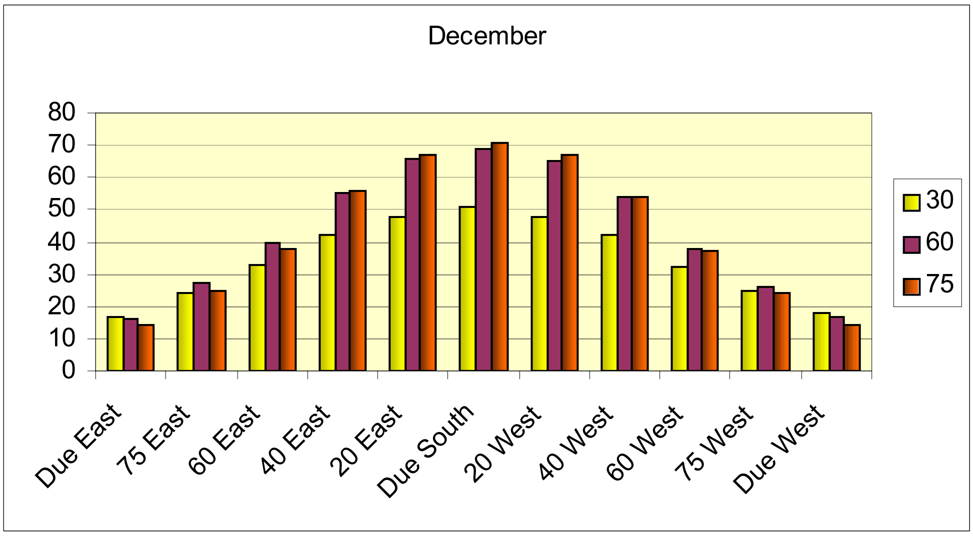
December
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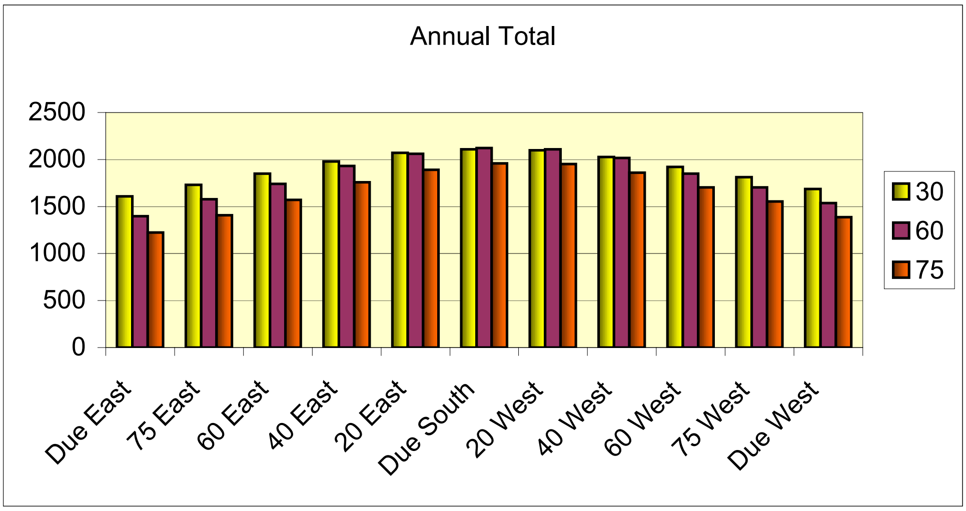
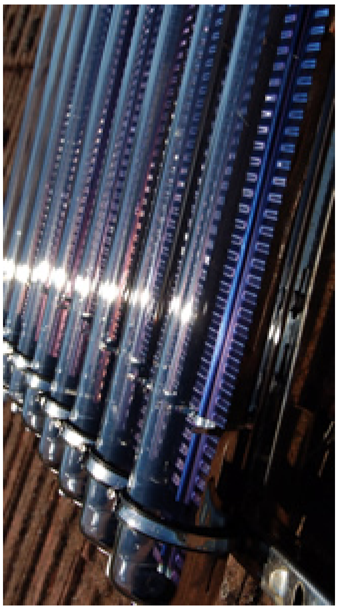


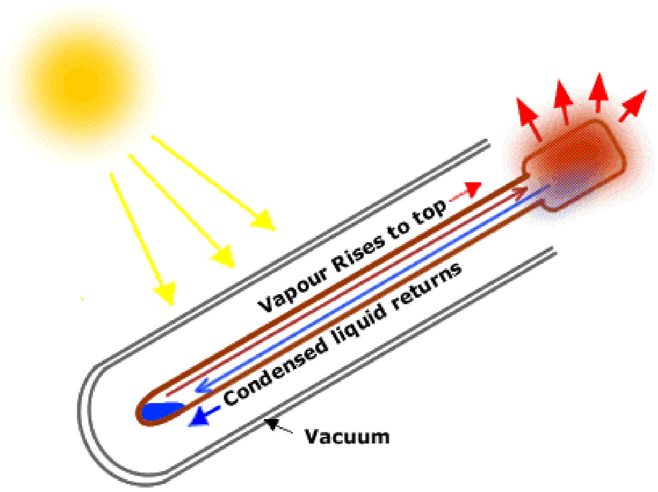
Solar Panel Physics

Vacuum Tubes



Vacuum tube collectors use a series of glass tubes that act like thermos bottles. The glass allows the light through, which heats up a fluid (distilled water or alcohol) inside an inner copper tube (also having a vacuum). The vacuum between the layers of glass prevents that heat from escaping back to the atmosphere on cold days. Because the distilled water (or alcohol) inside this pipe is under vacuum it boils at a very low temperature and so the steam rises to the top of the solar tube, acting very like a heat pump. The heat is then extracted via a Manifold and pumped to the hot water cylinder.

For these reasons Vacuum Tubes are very good at extracting energy and heating water to useful temperatures, even on cold and (light) cloudy days. On warm, sunny days, the performance of the vacuum collector is equal to that of the flat collector. But it will increasingly outperform the flat collector as the outside temperature decreases or light levels are reduced.



Each evacuated tube consists of two glass tubes made from strong borosilicate glass. The outer tube is transparent allowing light rays to pass through with minimal reflection. The inner tube is coated with a special selective coating (Al-N/Al) which features excellent solar radiation absorption and minimal reflection properties.

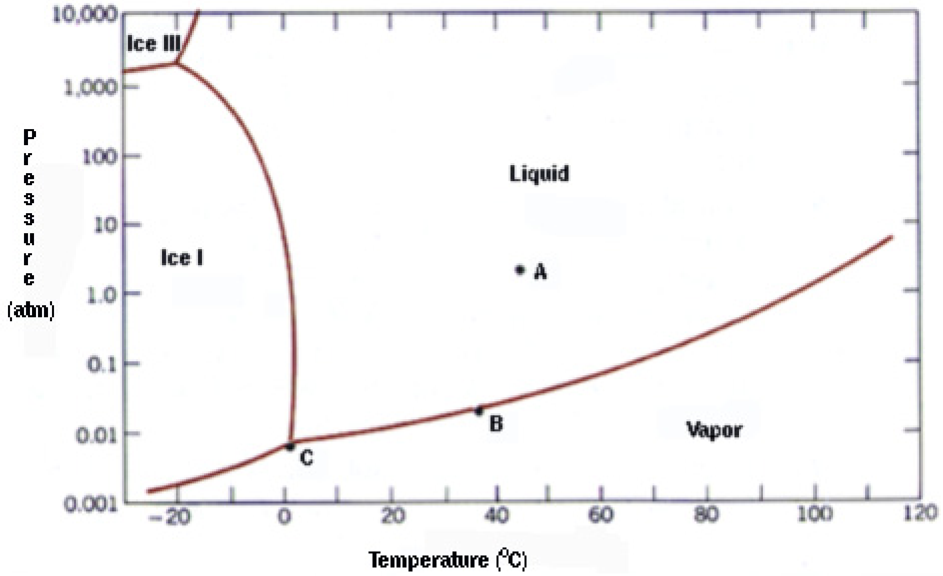
The top of the two tubes are fused together and the air contained in the space between the two layers of glass is pumped out while exposing the tube to high temperatures. This "evacuation" of the gasses forms a vacuum, which is an important factor in the performance of the evacuated tubes.
A vacuum is important because once the evacuated tube absorbs the radiation from the sun and converts it to heat, it won't lose it!! The vacuum helps to achieve this. The insulation properties are so good that while the inside of the tube may be 150C, while the outer tube is cold to touch. This means that evacuated tube water heaters can perform well even in cold weather when flat plate collectors perform poorly due to heat loss (during high Delta-T conditions).

In order to maintain the vacuum between the two glass layers, a barium getter is used (the same as in television tubes). During manufacture of the evacuated tube this getter is exposed to high temperatures which causes the bottom of the evacuated tube to be coated with a pure layer of barium. This barium layer actively absorbs any CO, CO_2, N_2, O_2, H_2O and H_2 out-gassed from the evacuated tube during storage and operation, thus helping to maintaining the vacuum. The barium layer also provides a clear visual indicator of the vacuum status. The silver coloured barium layer will turn white if the vacuum is ever lost. This makes it easy to determine whether or not a tube is in good condition.

Heat Pipe
To extract the heat from the tube, a special type of "heat-pipe" is used to absorb the energy and transfer it to the solar panel manifold. Heat pipes are not exclusively found in solar panels but are commonly used in laptop computers and air-conditioning systems. The principle behind heat pipe's operation is very simple and surprisingly efficient.

A heat pipe is simply a copper tube with a small amount of heat conducting fluid inside, and the air removed. When heated (even by a small amount) the fluid inside changes state from liquid to gas.

At sea level, water boils at 100C, but if you climb to the top of a mountain the boiling temperature will be less that 100C. (This is why tea tastes terrible when you go on a skiing holiday, due to the lower boiling temperature of water at altitude your tea cannot diffuse properly).



Triple Point of water, the temperature and pressure where ice, water and steam co-exist

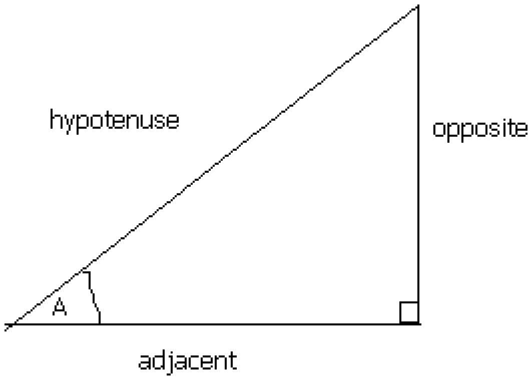
Based on this principle; by evacuating the heat pipe, we can achieve the same result. The heat pipes used in Wimex solar collectors have an operating point of only 30C. So when the heat pipe is heated above 30C some of the heat conducting fluid vaporizes.

This vapour rises to the top of the heat pipe transferring heat to the panel manifold. As the heat is lost at the condenser (top) to the manifold, the vapour condenses to form a liquid and returns to the bottom of the heat pipe to once again repeat the process.

Because of the very good insulating properties of the vacuum and the performance of the heat pipe, vacuum tubes panels are very good at extracting energy and heating water to useful temperatures, even on cold and (light) cloudy days. On warm, sunny days, the performance of a flat plate collector is almost to that of an equivalent vacuum tube collector. But the vacuum tube panel will increasingly outperform the flat collector as the outside temperature decreases or light levels are reduced. In fact they are ideal for Irelands climate!

To show how effective a heat pipe works, put one end into a cup of hot water and feel how quickly the top of the pipe gets hot. Compare this to a piece of copper tube.

Maths

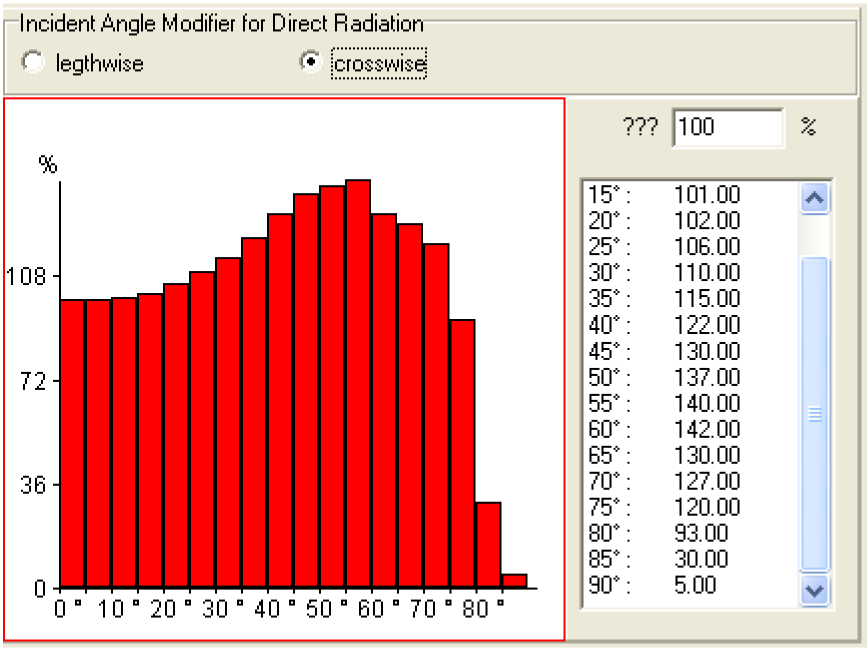


The cosine of the angle = $\frac{\text{the length of the adjacent side}}{\text{the length of the hypotenuse}}$

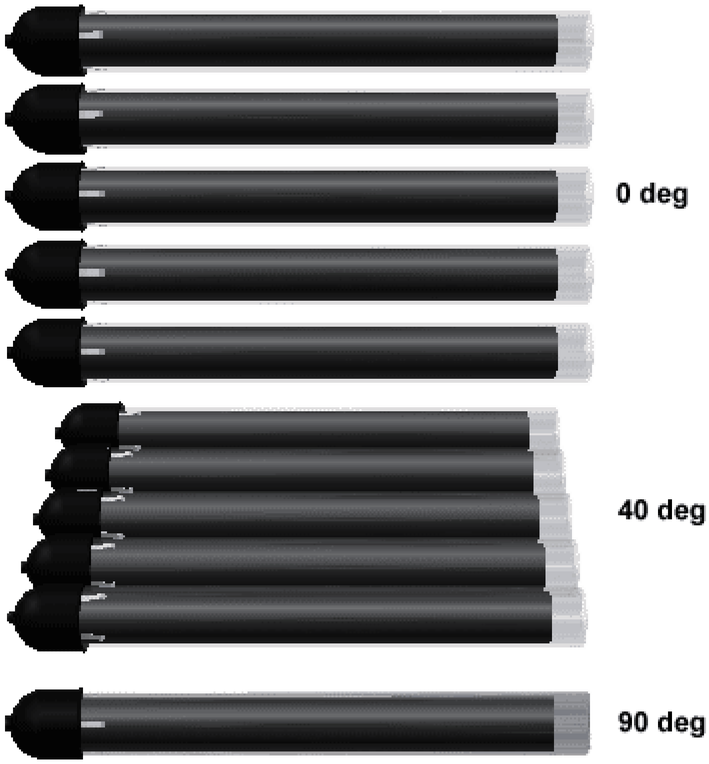
Imagine, the that sun is directly overheat, and that the solar panel is along the line of the hypotenuse. Then the length of the shadow is the equivalent to the amount of radiation falling on the panel. If A = 30 Degrees. Cos 30 = 0.866, so if 1000 watts is shining straight down then the panel will only see 866 Watts.

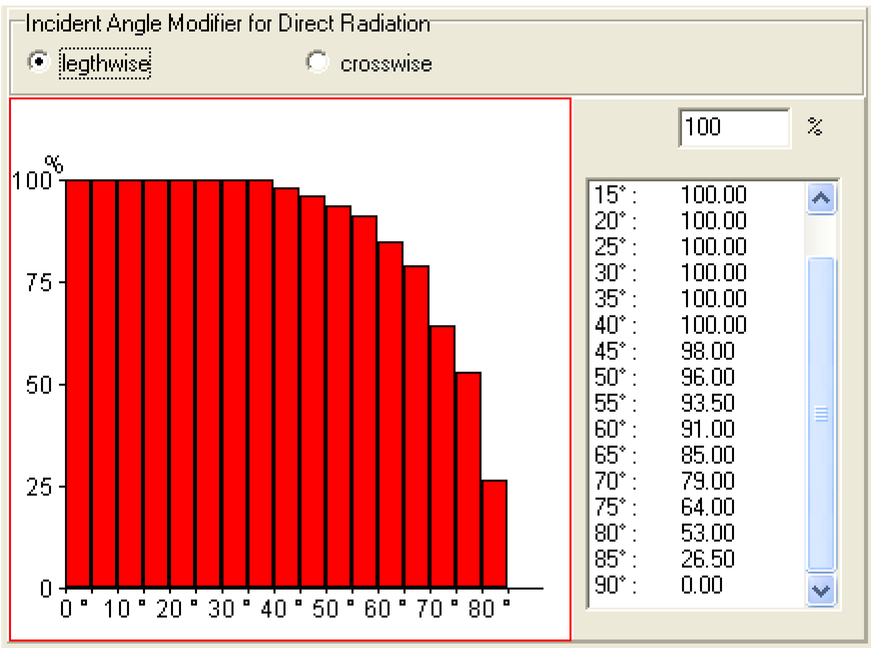
Incidence Angle Modifier

Performance measurements are normally taken with the solar insolation level measured perpendicular to the collector plane (i.e. facing the same direction as the collector). The IAM (Incidence Angle Modifier) values provides a performance factor, so that the output can be calculated when the light is not perpendicular to the collector.



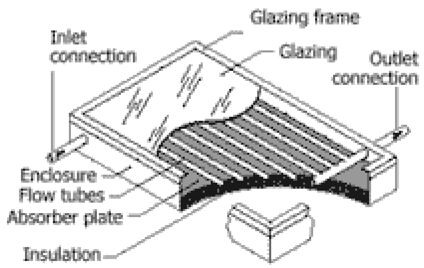
For flat plate collectors, 1 is the maximum value, dropping off in both morning and afternoon. Evacuated tube collectors, provide values in excess of 1, because as the sun moves across the sky, the solar panel still gives 100% output for several hours, even though the shadow size is getting smaller. Compared to a flat plate, the vacuum tube give a more consistent output over a longer period of the day.



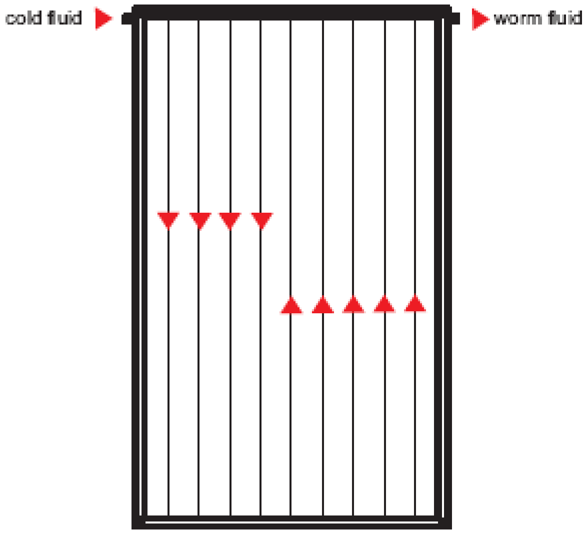


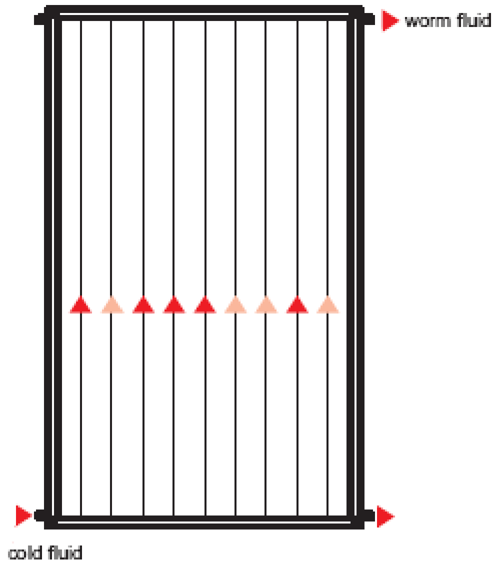
Flat Plate Collectors

Sunlight passes through the glazing and strikes the absorber plate, which heats up, changing solar energy into heat energy. The heat is transferred to liquid passing through pipes attached to the absorber plate. Absorber plates are commonly painted with "selective coatings," these coatings absorb UV and visible radiation, but are reflective to infrared so that they retain heat much better than ordinary black paint. Absorber plates are made of copper welded to a copper pipe.



Internal Layouts





Plumbing

A word on Automatic Air Eliminators

Pump stations normally have a feed and drain point which allow the connection of a solar filling pump to circulate water through the system and thus eliminate air. Our experience has been that air vents generate more problems than they eliminate and should not be fitted.

Expansion Vessel Sizing

Water expands by 4% going from 10C to 110C. In heating systems you normally work out how much water there is in a system and multiply by 0.0833 (i.e. 8%). In Solar because of the much greater temperatures that can arise and because of panel saturation, 25% is recommended. In solar installations a minimum size of 18 litre expansion vessel should be used.

Boyles Law

The relationship between volume and pressure. The law assumes the temperature to be constant, however for our purposes we'll ignore this. In any case the temperature is measured from absolute zero, (-273 C).

$$\frac{V_1}{V_2} = \frac{P_2}{P_1} \quad \text{or} \quad \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

V1 = original volume
V2 = new volume

P1 = original pressure
P2 = new pressure

Normally, expansion vessels come pre-charged to 1.5 bar. So if we fill our solar system to 2.5 bar, this will push the membrane of the vessel back and partially fill the expansion vessel. We can use Boyles law to estimate how much water is held in the expansion vessel.

P1 x V1 = P2 x V2

P1 = 1.5 + 1 = 2.5 bar (the addition of 1 bar is for the atmospheric pressure).
V1 = 18 litres

P2 = 2.5 +1 = 3.5 bar (again, the addition of the 1 bar is for the atmospheric pressure)

2.5 x 18 = 3.5 x V2
45 / 3.5 = V2 , solving gives V2 as 12.85 litres of **AIR** LEFT in EXPANSION VESSEL
This means that we have 18 litres – 12.85 litres of water in the expansion vessel, or **5.15 litres.**

Summary: *charging a solar panel system with a 18 litre expansion vessel to 2.5 bar gauge pressure means that there is just over 5 litres of water in the expansion vessel.*

Now what happens to the system pressure if the solar pump doesn't operate during a period of hot weather?

The system water (or heat transfer fluid) gets warm and expands by about 4%, so assuming that we had 30 litres in the system, an extra 1.2 litres (4% of 30 litres) expands into the expansion vessel. Also assume that the panel saturates and the manifold becomes so hot that all the water is pushed out by rising steam pressure. This could equal another 3 litres.

Now we have an extra 4.2 litres of water in the expansion vessel, or 4.2 litres less air volume.

P1 x V1 = P2 x V2

P1 = 2.5 bar (the addition of 1 bar is for the atmospheric pressure).
V1 = 18 litres

P2 is now unknown.

V2 = 18 litres – (5.15 +4.2) = **8.65 litres of AIR left** in vessel

P1 x V1 = P2 x V2
2.5 x 18 = P2 x 8.65
45/8.64 = P2
5.2 Bar absolute, but the **pressure gauge would read 4.2 bar** because 1 bar is for the atmospheric pressure

2.5 x 18 = 3.5 x V2
45 / 3.5 = V2 , solving gives V2 as 12.85 litres of **AIR** LEFT in EXPANSION VESSEL

What happens if we used a 10 litre expansion vessel instead?

P1 x V1 = P2 x V2

P1 = 1.5 + 1 = 2.5 bar (the addition of 1 bar is for the atmospheric pressure).
V1 = 10 litres

P2 = 2.5 +1 = 3.5 bar (again, the addition of the 1 bar is for the atmospheric pressure)

2.5 x 10 = 3.5 x V2
25 / 3.5 = V2 , solving gives V2 as 7.14 litres of **AIR** LEFT in EXPANSION VESSEL

This means that we have 10 litres – 7.14 litres of water in the expansion vessel, or **2.86 litres of water.**

The panel now saturates and an extra 4.2 litres of water expands into the expansion vessel, or 4.2 litres less air volume.

P1 x V1 = P2 x V2

P1 x V1 = 25, (2.5 x 18) P2 is now unknown.

V2 = 10 litres – (2.86 +4.2) = **2.94 litres of AIR left** in vessel

P1 x V1 = P2 x V2

2.5 x 10 = P2 x 2.94
25/2.94 = P2

P2 = 8.5 Bar absolute, but the **pressure gauge would read 7.5 bar** because 1 bar is for the atmospheric pressure.

However our safety valve would blow at 6 bar gauge pressure or 7 bar absolute.

Summary

Result 1: *charging a solar panel system with a **18 litre expansion vessel to 2.5 bar** gauge pressure means that there is just over **5 litres of water in the expansion vessel.***

Result 2: *if this solar system goes into **saturation** and generates an additional 3 litres steam + 1.2 litres of water expansion, then the **system pressure rises to 4.2 Bar**.*

Result 3: *a 10 litre vessel subjected to these conditions will cause the safety valve to lift.*

Boiling point of water at different pressures.

Increasing the pressure in a solar system helps increase the boiling point, so that water can be still pumped around the system at temperatures above 100 C.

Pressure	Boiling point	Specific volume (steam)	Density (steam)
bar	°C	m3/kg	kg/m3
0.9	96.71	1.869	0.535
1	99.63	1.694	0.59
1.5	111.37	1.159	0.863
2	120.23	0.885	1.129
3	133.54	0.606	1.651
4	143.63	0.462	2.163
6	158.84	0.315	3.17

Care must be taken that panels should never be disconnected under pressure if the temperature is above 100C. Water at 2.5 bar (gauge pressure) boils at 140C. If a solar panel containing very hot water is suddenly depressurised; some of the water within the panel will “flash” to steam, each litre of water in the panel potentially turning into 1700 litres of steam.

Pipe Sizing

DN12 pipework with a combined flow and return length of up to 50 meters will provide a sufficient flow rate to transfer 3KW of heat from a solar panel. This includes the flow rate degradation caused by adding up to 40% Propylene Glycol.

This is sufficient flow rate for a 6m2 panel.

Sizing pipework correctly reduces the amount of water within the pipework, reduces heat losses for each insulation size, accelerates the response of the panel and generally increases system efficiency.

Note: DN12 flexible stainless steel pipe is sufficient for domestic solar water heating systems up to 6 m2, mounted at a distance up 25 meters away from the cylinder.

Pump Speed Selection

Solar panels generally use much lower flow rates than conventional heating systems as a result, the solar circuit is running at the lower end of the pumps designed operating range. Changing the pump speed from 1 to 2 generally results in a flow rate of increasing by a third. Changing the pump from speed 2 to speed 3 has only a tiny effect. (about 5% extra flow rate for double the pump power use).

Note: *Generally a solar pump will be* ***set to setting 2****, setting 3 will only result in more electricity being used.*

Addition of Anti-Freeze

The higher the proportion of Anti-Freeze in a system, the less efficient it will be.

Types of Anti-Freeze

Ethanol (alcohol) cannot be used in solar systems because it has a low boiling point of 78C.

Ethylene Glycol is used in car radiators as an anti-freeze, however the ingestion of just 2 tablespoons of Ethylene Glycol can be fatal in adults, and unfortunately because of its sweet taste, animals or children may consume large volumes if exposed to it.

DO NOT USE IN ANY CIRCUMSTANCES

Propylene Glycol in low concentrations is generally deemed to be safe if ingested and indeed is used as an additive in cosmetics and food (E number 1520). For this reason it is popular within Solar Systems.

However the use of any anti-freeze within a solar system does have some disadvantages and suppresses the efficiency of the system.

Thermal heat capacity
Thermal heat capacity: is very high and at 3590 J/kg/K is almost as good as water at 4187 J/kg/K.

Thermal Conductivity
However the disadvantages are more apparent when the thermal conductivity is taken into account. At 0.323 W/mK it represents 45% worse heat transfer than when compared to water at 0.58 W/mK.

In effect this means that the temperature difference across each heat exchange surface will double if pure Propylene Glycol is used. This decreases the efficiency of the solar system. (A heat pipe vacuum tube has an additional heat exchange surface from the heat pipe manifold to the glycol within the manifold).

Viscosity
The most serious disadvantage with Propylene Glycol over other types of anti-freeze is its very high viscosity. The viscosity however decreases with increasing temperature. Water / Propylene Glycol mixes with up to 50% can be offer 5 times the pumping resistance at –10C. At 20C a **doubling of pipe resistance** should be allowed for. However above 40C, the derogation become much less pronounced.

Lower ratios (e.g. 20%) obviously offer less resistance. This has implications for pipe sizing calculations.

Corrosion Protection
Propylene Glycol offers better corrosion protection than water. It is however still a good idea to add an corrosion inhibitor to the anti-freeze mix.

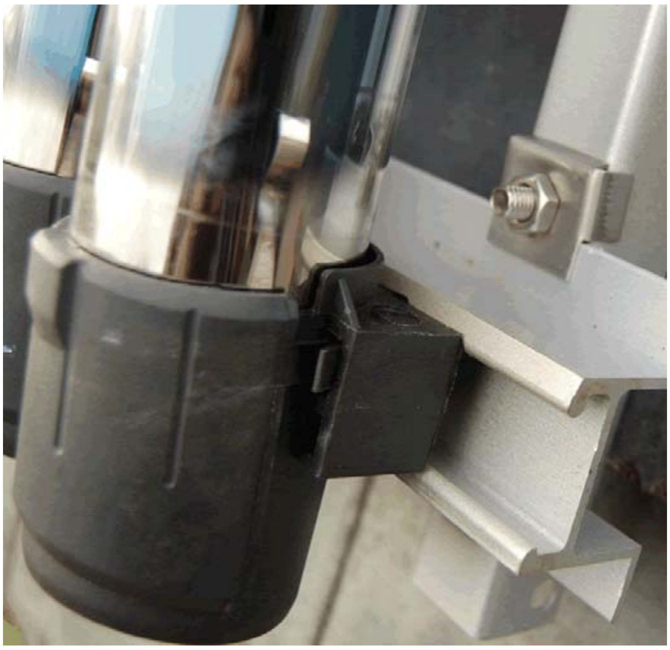
Fluxes contained in soft solder normally contain chlorides which react with Propylene Glycol and should not be used. Brazing or silver solder is compatible.

Freezing Protection
10% Freezing limit –2C
20% Freezing limit –6C
25% Freezing limit –9C
30% Freezing limit –13C
40% Freezing limit –20C

Mounting Instructions for a Vacuum Tube panel on a Tiled Roof

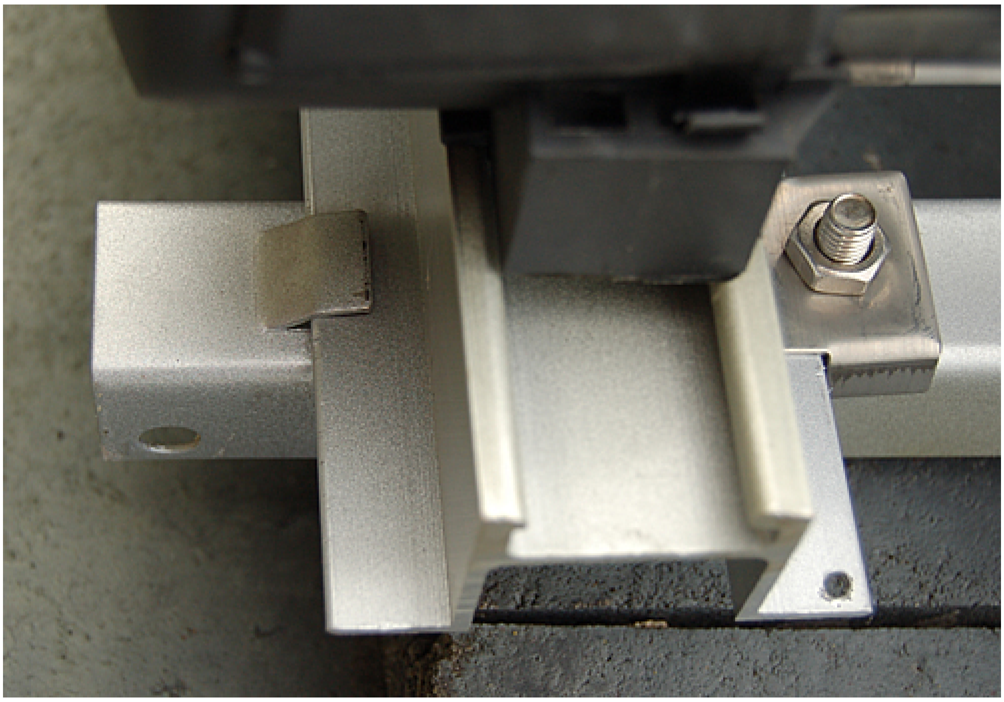
Step 1. Assemble the Frame

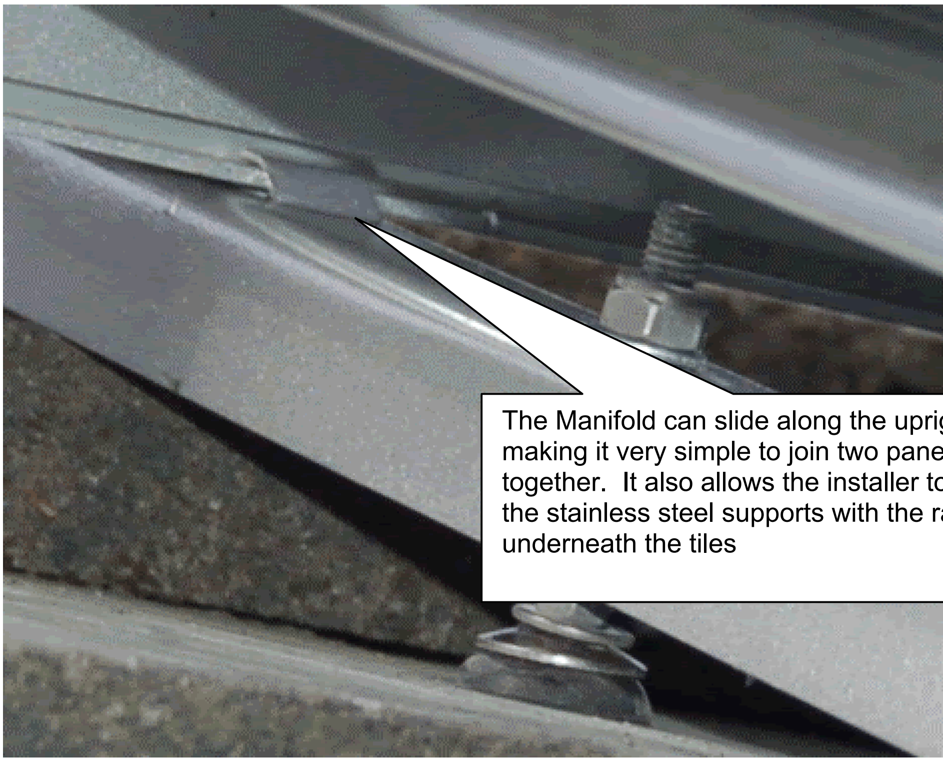
The frame consists of 3 uprights (2 for 18 tube panel), a manifold and the bottom cross bar. Assemble the frame using the supplied nuts, bolts and stainless steel fittings. The bottom cross bar pictured below should be positioned so that the wider lip is pointing up. This allows the black tube holders to clip in.



The manifold is attached to the frame with 6mm bolts, while the frame is assembled with the 8mm bolts provided. (14mm, 10mm spanners and/or sockets required).

Apply “thread-lock” to the bolts as the frame is assembled.   It is normally easier to assemble the frame at ground level and use ropes or straps to hoist to roof level.

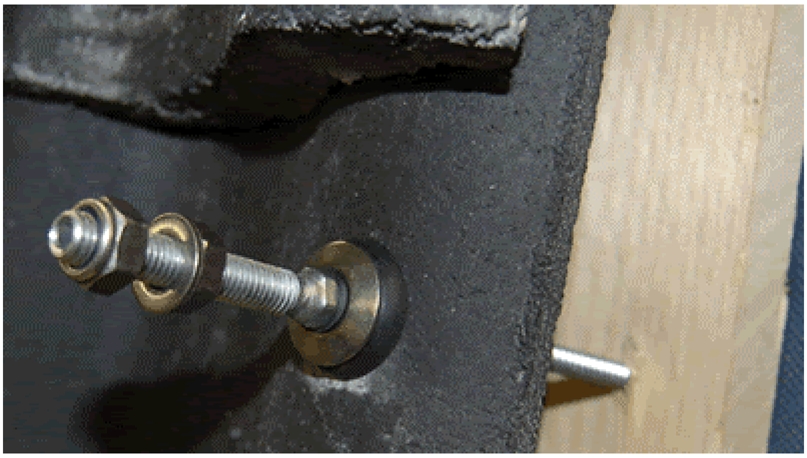




The Manifold can slide along the uprights making it very simple to join two panels together. It also allows the installer to match the stainless steel supports with the rafters underneath the tiles

Step 2. Attach the frame to the roof

The next step is to fix the supporting frame to the roof. Locate the centre of the rafter, this can be done by lifting tiles, or using a pair of strong magnets. Drill a 8 mm hole through the tile using a masonry (or diamond) drill bit. Screw the solar bolt through the hole in the tile and into the rafter below. Where the rafters cannot be located or if the tile profile does not match the rafter below, a noggin can be used instead.



Note that the solar bolt should be attached at the highest point in the tile profile, so that rain will have a natural tendency to flow away from the seal. Do not mount the screw in the tile "valley" unless there is a route for rain water to flow unimpeded down the roof.
It is good practice to use “Tec-7” under the seal, so that the seal is stuck permanently to the slate/tile.

It is also recommended that the solar bolt is screwed into the wood/rafter a depth of at least 2 inches or 50mm. A baton with a typical depth of 25mm is therefore not suitable.

Disclaimer, note that some house particularly wood frame houses use heavier batons and therefore, the spacing under the tile can change. It is the installer’s responsibility to ensure that sufficient penetration and the rafter is in good enough condition to give the required strength.

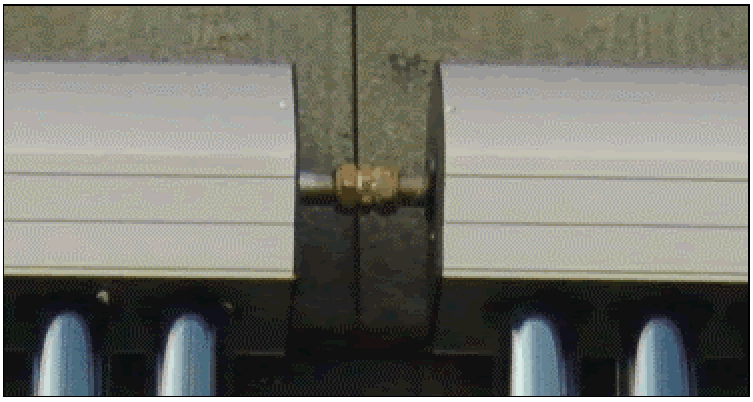
In some cases, particularly with Spanish Roll type tiles, it may be necessary to use a longer (150mm instead of the standard 130mm) solar bolt.

Attach panel frame to threaded bar of the solar bolts.

Step 3. Attaching Pipework to the Panel

The manifold connection is a 22mm copper pipe. It is normally easier to make the connections before the panel is brought up to roof level. Because 10mm pipe is used on many hot water installations, it is necessary to reduce the 22mm connections to 10mm.

Two panels can be joined together using a "610" straight 22mm compression coupler. Slacken off the bolts holding the manifold to the frame, slide the manifold away, introduce the coupler and slide the manifold back into position and re-tighten.



Normally 22mm 615 Compression elbows are used at the ends of the panel, and converted to mate with the pipe-work. A 316 with 22mm on one side and ½" BSP on the other allows a very simple connection to DN12 flexible stainless steel pipework.

Step 3. Bringing Pipework through the Roof.

Use ½" 100mm long nipples and backing nuts to penetrate the roof. Use 340 fittings to convert the compression end of the nipple to a flat surface enabling a good seal to the washer and stainless pipe.

Seal the backing nuts with the tile using a generous coating of Tec-7 to leave a completely watertight seal.

Only insulate after the system has been pressure tested (so that leaks can be seen during pressure testing) with high temperature waterproof insulation.

Step 3. Plumbing & Pipework

Pipework to and from the panel should be in copper or flexible stainless steel, with high temperature insulation, all gaps in the insulation should be closed.

Due to high temperatures and pressures that can exist if the panel stagnates, plastic piping (e.g. Qualplex) should never be used within the solar circuit.

Installing an in-roof collector.

The Gasokol in-roof panel array is made up of 2 or more panels. There is always a "lead panel" supplied. This is the panel with the built in sensor port.

The lead panel must always be mounted on the right hand side of the roof. The output of this panel should be connected to the top of the solar coil.

Step 1. Remove the tiles from the chosen area, the upper part of the panel should be at least two rows down from the ridge tile.

Step 2. Carry the lead panel up to the roof using the straps supplied. There are wooden laths at the back which sit onto the roof batons. The lead panel with the sensor connection must be the installed to the right of any other panels.

Step 3. Carry up the remaining panels to the roof and slide from the left until the joining edges interlink.

Step 4. Connect the pipework at the top of the panel. The seal is already present and does not require any sealing compound. Connect the roof pipes.

Step 5. At this stage it is worth pressure testing the panels, to check fittings are tight, as it is very difficult to correct any leaks when the panels are flashed in place. Use the filling station to fill and flush with the water/antifreeze mix and pressurised to just 4.5 bar for testing. Normal operating pressure will be 3-3.5 bar Take care that there is an expansion vessel and safety valve on the line, so that if the sun heats the panel there is expansion path available. The pressure vessel must be sized not only to absorb the increased expansion but also the increased volume as steam forms in the collectors.

Note: it is not possible to empty the panel so the antifreeze mix should be used at this stage.

Step 6. Screw down the panels using the 150mm long screws and black spacers. Attach the L-Brackets to the side of the panel.

Step 7. Fit moulded fittings to bottom of the panels

Step 8. The middle aluminium strip covers can now be fitted. A rubber mallet should be used for this. The screw hole must be at the top. Screw into place.

Fitting the Flashing

When ordering flashing it is necessary to specify whether the roof is tiled or slated. The tiled flashing has a skirt at the bottom which adjusts to the tile profile. It is sometimes also necessary to add an extra baton thickness on the bottom row to bring the tile out to meet the flashing.

When ordering flashing, it is necessary to specify whether the roof is **tiled** or **slated.** The tiled flashing has a skirt at the bottom which adjusts to the tile profile. It is sometimes also necessary to add an extra baton thickness on the bottom row to bring the tile out to meet the flashing.

Step 1. The lowest left part of the flashing is fitted first. Screw home.

Step 2. Fit the bottom flashing on the left and middle next. There is a joining piece must be flush with the panel. This is to cover the expansion gaps of 2 panels.

Step 3. The side flashing is made up of two sections, push the bottom section up until it is level with the bottom of the panel. Engage the lip of the flashing with the edge of the panel. Push the top section over the bottom until it is level with the marker line. Screw to side of panel. Fix other side of the flashing with small clips supplied.

Note: Do not deform the flashing when screwing down the clips as it may allow water to penetrate.

Step 4. Fit the top left hand side flashing next, push the flashing up under the tile, engaging the profiles as you do. Fix with 2 clips, leaving at least an inch from the top and bottom.

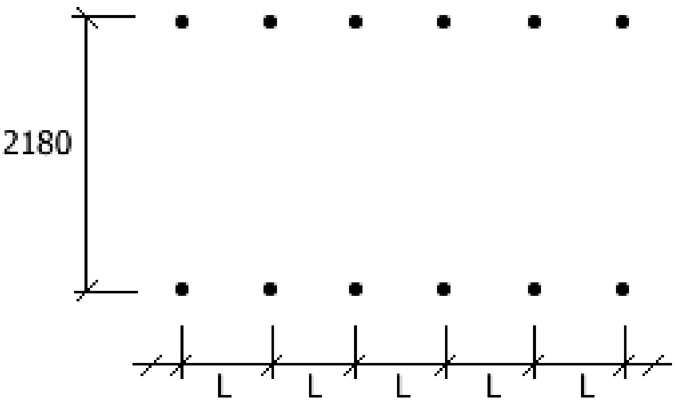
Step 5. Slide the flashing on the right into the groove on the left, continue for each panel working from the left.

Step 6. Fix the foam to the top and sides of the panel. Replace the tiles to leave about ½” around the panel.

Step 7. Adjust the skirting at the bottom to match the tile profile.

Installing the on-roof flat plate collector.

The Gasokol 0n-roof panel array is made up of 2 or more panels. The plumbing connections are joined at the top, and the panels are mechanically held in place using an aluminium profile.



Step 1. Decide where the panel is to be positioned, using the table below mark the bolt holes in the tile/slate.

No. of panels	2	3	4	5	6
L	750	877	940	815	860

Leave 350 mm at the edge.

The holes can be moved to match up with the rafters below.

Do not mark the holes in the bottom of the tile valley or too close to the edge of a tile. Drill the holes in the tile/slate with a 8mm diamond or masonary drill bit.

As heavier bolts are needed for flat plates than for vacuum tube panels to take extra wind loading, pilot holes should be drilled in the rafter/noggin below.

Screw in the bolts using an allen key or spanner. Do not overtighten as this may crack the slate/tile.

To improve the seal, coat the bottom of the seal with Tec-7, this will glue the seal to the tile giving a much more robust fitting.

Step 2. Fix stainless steel bracket to top of bolt and join to aluminium rail using the fixings supplied. Do not over-tighten the bracket at this stage as it will need to be moved in the next step.

Step 3. Carry the panels up to the roof using the handles supplied, and sit onto the bottom aluminium rail.

Step 4. Join plumbing unions at the top of the panel, move rails into lock panel in its final position.

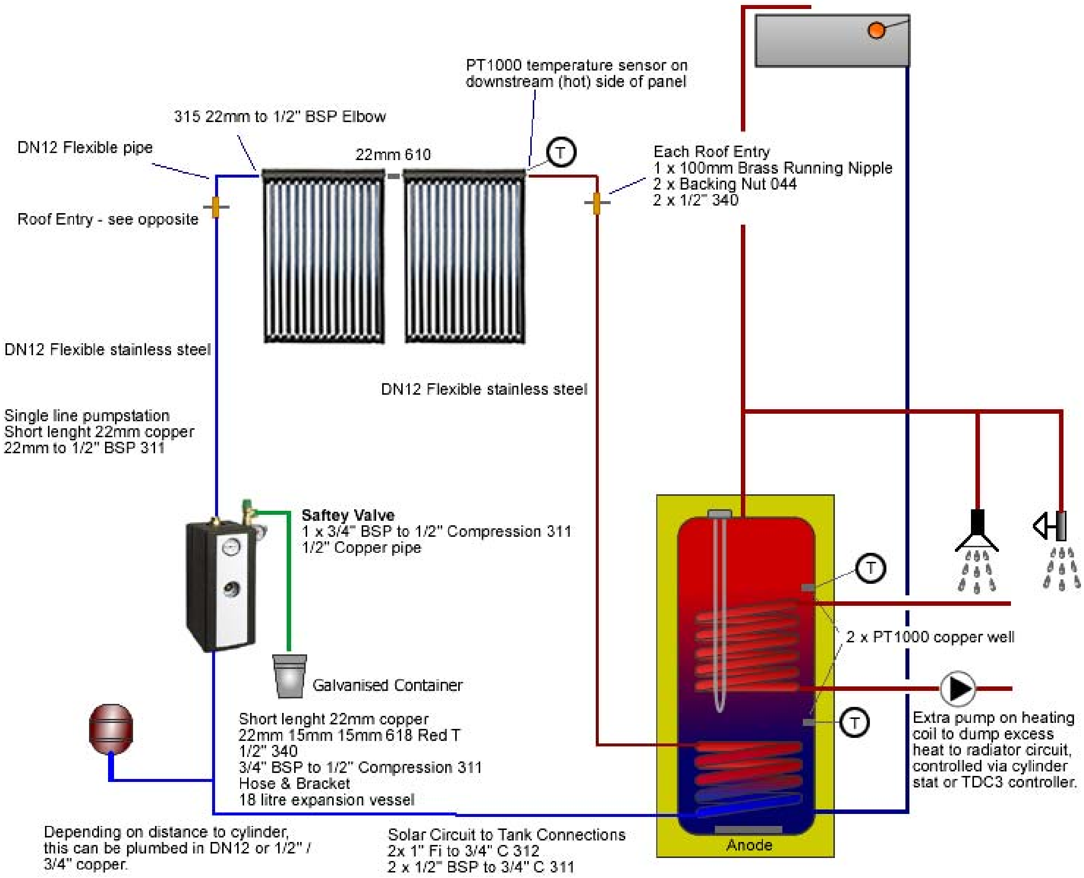
Step 5. Fit T-Piece with sensor pocket to right hand panel. Join flexible steel pipes to connections. Take care not to twist the panel pipework when joining.
Step 5. Fit T-Piece with sensor pocket to right hand panel. Join flexible steel pipes to connections. Take care not to twist the panel pipework when joining.

Step 6. Use the self tapping screws to provide the final fixings.

Step 7. Bring the flexible stainless pipework in through the vent tiles.

Step 8. Connect and fill as for other panels

Plumbing Diagram



This solar circuit is designed to fail safe and keep most of the solar components cool even in the event of a power failure and consequential panel stagnation.

Note: By placing the expansion vessel below the pump station as shown in the diagram below, the system stays cool even if the panel stagnates (e.g. power cut in summer). This is because, if the manifold water turns to steam, the displaced water in the solar pipework is forced into the expansion vessel. This water cannot travel through the pumping station because of the non-return valve, so it travels down the other pipework and through the coil in the tank before it reaches the expansion vessel. This means that the rubber membrane is always and pump components are always in the coolest part of the circuit.

Single Line Pumpstation

The Sorel Pumpstation supplied with an expansion vessel connector.

Note: If a standard (heating) expansion vessel is used, the non-return valve shown on the expansion vessel bracket in the pump-station can be removed, a expansion vessel then fits the exposed threads.

Note 2: A solar type expansion vessel should always be used if the vessel is being mounted at the top of the pumpstation

Expansion Tank Connection
The 18 litre expansion vessel is not mounted directly on the pump station as is normally the case, but rather on the return line from the solar coil. This is the coolest part of the solar circuit. Because the non-return valve is below the safety valve within the pump station, all system expansion is then forced through cylinder coil. There is a direct route between the panel and the safety valve so the system remains safe.

Note: Mounting the expansion vessel upside down as shown in the picture above simplifies the removal of air from the vessel connection.

Plumbing components for vacuum tube system.

The tables below are split up into the various areas and are designed to give the installer a list of plumbing components required for most eventualities.

The list below should be compared to the plumbing diagram for details on where the components should be fitted.

Copper Cylinder Replacement Components	
¾" 315 Compression Elbows	10.00
¾" 310 Compression Couplers	2.00
¾" ½" 318 Reducing Tee	1.00
½" 312	1.00

Auto Air Vent ½" BSP Thread	1.00
PT1000 CU tank pockets	2.00
1 litre Inhibitor	1.00

Pump Station / Cylinder & Expansion Connection	**Qty**
Short Length 22mm Copper	2.00
22mm 15mm 15mm 618 Reducing Tee	1.00
1/2" BSP MI x 22mm Compression 311	1.00
1/2" Compression to 1/2" BSP converter 340	2.00
½" FI ¾" CU 312	2.00
¾" 311	2.00

DN 12 Roof Components – 2 vacuum panels, 2 roof entries	**Qty**
½" 100mm running nipple	2.00
½" backing nuts	4.00
1/2" Compression to 1/2" BSP converter 340	4.00
1/2" DN12 Flexi Hose with 1/2" BSP Connections -10"	2.00
1/2" BSP MI x 22mm Compression Elbows 316	2.00
22mm 610 Compression Couplers	1.00

TDC3 Electrical Overheat Pack - extra pump	**Qty**
5 Amp junction box	1.00
Circulating pump	1.00
Pump Valves (pair) 3/4" compression	1.00

Mechanical Overheat Pack	**Qty**
ESBE thermostatic Valve (no overheat block)	1.00
½" 312	4.00
½" Flap type NRV	1.00
½" 311 (to fit NRV)	2.00
1/2" 318 Equal Tee	1.00
1/2" Compression to 1/2" BSP converter 340	4.00
Note: Radiator/ Radiator Valves and Pipework not incl.	

DN12 Pipework & Insulation	**Qty**
DN12 Solar 20m twin pre-insulated pipe	1.00
22mmx19mm K-Flex Solar	2.00
Split Ring, Nut & Washer	4.00

Electrical Pack	**Qty**
Switched Spur Box	1.00
Surface Mount Box	1.00
5 Amp junction box	2.00

Immersion Switch Pack (anti-Legionella)	**Qty**
Flash Immersion timer single channel	1.00
20A juction box	1.00

Gasokol On-roof components (anti-Legionella)	**Qty**
DN16 Threaded End T-Piece with sensor pocket (07033)	1.00
¾" coupler (supplied with DN16 Flexible hose)	1.00
1 meter flexible hoses – DN 20	2.00
¾"FI to ½" Compression 312	1.00
½" 311	1.00

Gasokol In-Roof Components	**Qty**
1/2" BSP MI x 22mm Compression 311	1.00

22mm copper pipe with screw connections	1.00

Checking the cylinder for foam
Check the cylinder for errant pieces of foam prior to connecting up. A good rinse with a garden hose is helpful. Loose pieces of foam can get trapped in elbows, pipes and taps leading to customer complaints about a drop in water pressure. These pressure drops can be very difficult to find!

Inhibitor
It is good practice to also use an inhibitor like Fernox F1 within the solar system. It is rated to above the temperature that a solar system will reach. Fernox requires dosing levels of 0.5%, while other products such as Everrad Inhibitor require dosing levels of 1%. The average solar system uses about 20 to 30 litres of water, to this means that 200 to 300 ml of product will be required. The remainder of the inhibitor can be used in the central heating system. It is compatible with Propylene Glycol antifreeze.

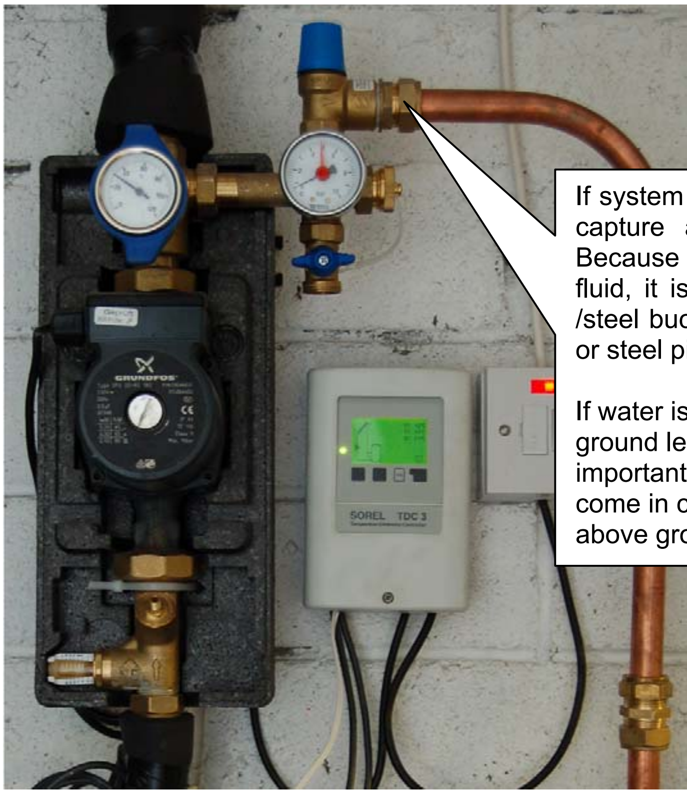
Internal Leak Sealant
We have had some less than satisfactory experience regarding internal leak sealant, this may have resulted from the product being activated while it was being circulated with the filling pump station. We found reduced flows within the solar circuit and we were forced to rectify the situation by flushing with clean water and refilling.

Power Failure
If the pump cannot operate (e.g. power failure) the panel will continue to receive energy from the sun, and in many cases will reach temperatures that cause the water inside the panel to boil and expand into steam. Because the non-return valve and expansion vessel configuration forces all the resulting expansion into the cylinder coil (where it cools), the majority of the circuit is kept cool (pump station, expansion vessel, and thermostatic valve).

Safety Valve Pipework
Pipe the safety valve to a galvanised steel bucket below the pumpstation. Make sure that there is no rise in the pipework. Use at least a ½" copper pipe to the drain point. Plastic pipe or indeed a plastic container may melt if the safety valve releases superheated water under stagnation conditions.

If anti-freeze is present in the system, then the pipework cannot be brought to drain and must be captured in a suitable container.

DO NOT bring the safety pipework from the hot-press to an overflow in the attic. A fall must be present in the whole length of pipework.



If system is filled with Anti-freeze, it is necessary to capture any discharge in a suitable container. Because the discharge is likely to be superheated fluid, it is important to collect this in a galvanised /steel bucket. It should also be plumbed in copper or steel pipe.

If water is used, then the drain can be piped to ground level or into a down-pipe. It is very important that it cannot be discharged where it can come in contact with people. i.e. Discharge to just above ground level.

Dumping Excess Summer Heat

Because the system is designed to produce useful heat from early spring to late autumn, the panel will produce too much heat in the summer months. Many solar panel suppliers simply keep the panel sizes small and turn off the panel in the event of a cylinder overheat. However this leads to thermal stresses and degradation of the insulation, keeping the panel small and water storage large can overcome these problems to some extent, but the correct way is to dump the heat into the house radiators, or an attic radiator (on the solar circuit), or course this allows the solar panel installation to be much larger and hence far more effective throughout the year. There are several methods which are described below.

Installation of a second pump on the heating system.

Perhaps the simplest way to install a second pump on the heating coil. Any summer valve must however be left in the open position for this to work correctly.

The TDC3 controller has a function which can turn on a relay (which we connect to the second pump) when the cylinder reaches a pre-set temperature. This circulates the water in the heating system through the heating coil without turning on the boiler and causes the nearest radiators to heat cooling the cylinder.

In practice, this is a very good solution, it is quick and easy to install and brings excess heat into the house. It does not lead to overheating in summer as the panel output in peak conditions is the equivalent of one full radiator, and will not work at night (for obvious reasons). Feedback from customers has been excellent, as they have used this to dry clothes in good weather.

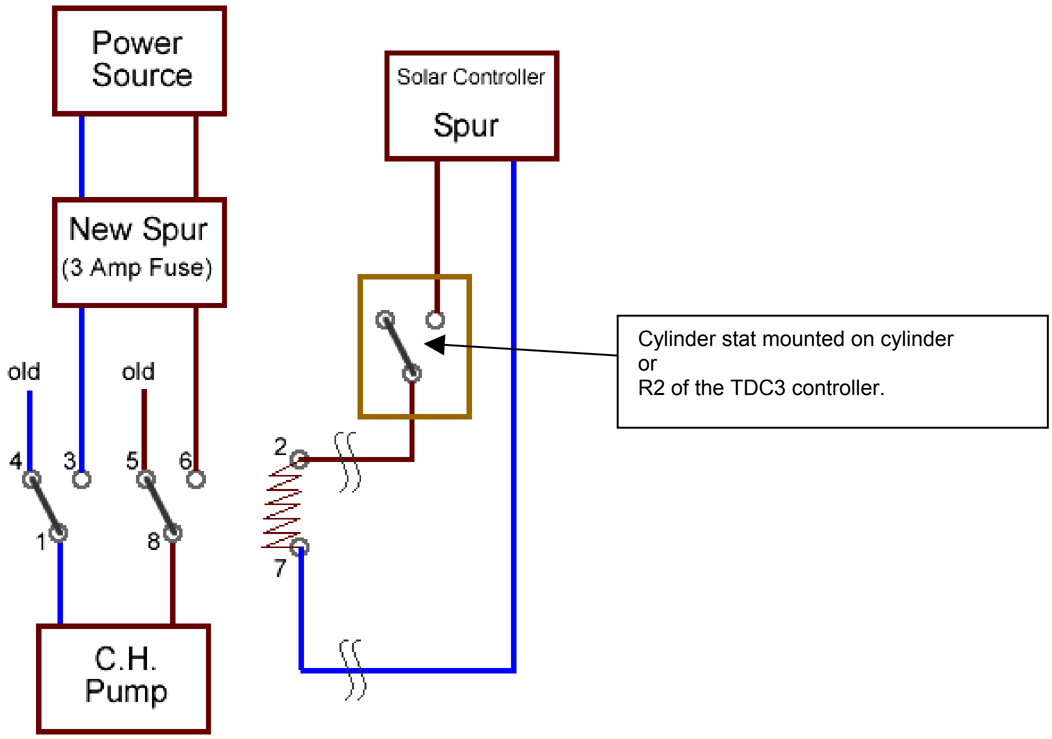
A special feature of the TDC3 controller is the ability to turn on a relay for 5 seconds every day. This prevents a pump that is seldom used from seizing.

A cylinder stat can also be used to control the pump.

Use of the existing Central heating pump to dump heat.

Sometimes, it is easy to access the existing central heating pump and if so it can be activated to dump excess summer heat. A relay is required so that powering up the central heating pump does not also power up the boiler. The following diagram can be used with either a cylinder stat or the TDC3 relay (R2) output.

Note that both the neutral and live are switched through the relay. This makes sure that the correct live and neutral are connected to the pump preventing the ELCB from detecting current imbalances and tripping.



Simply wiring the pump via the cylinder stat is likely to also start the boiler, delivering more heat in an over-heat condition!

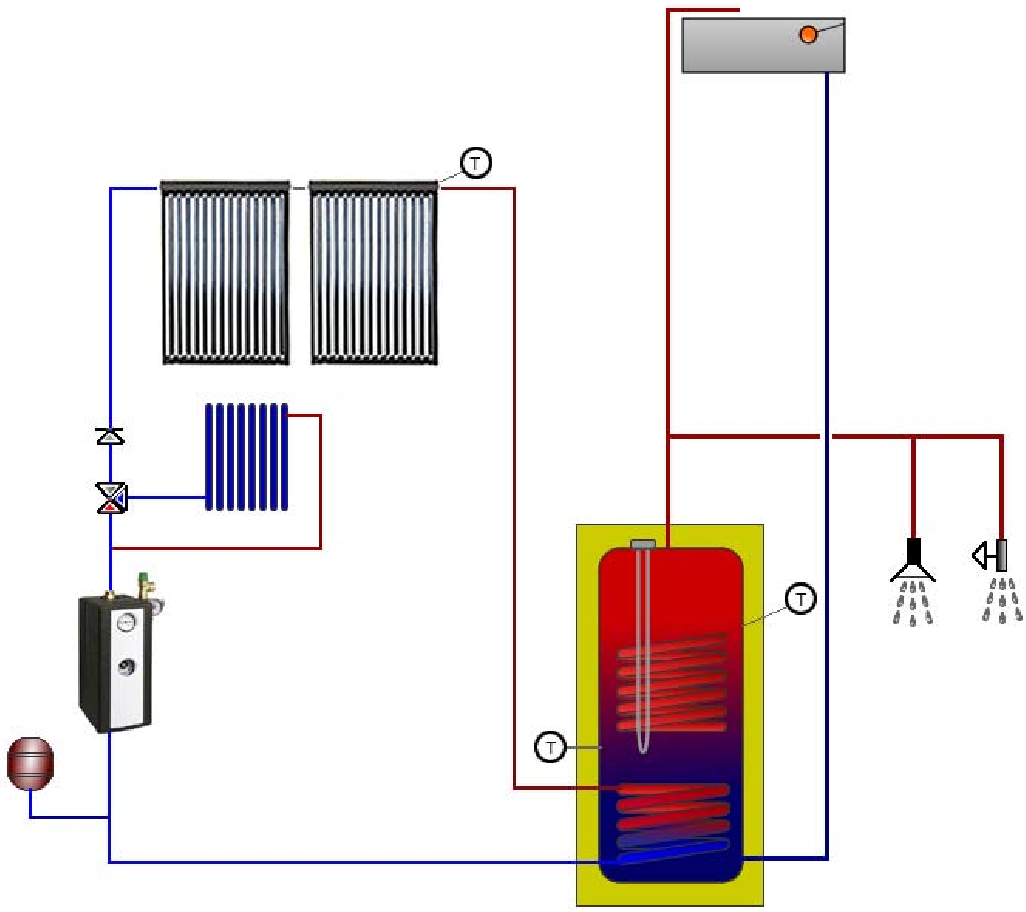
How to wire the Cylinder Stat and Relay

Step 1. **Isolate and make sure power cannot be reconnected without you knowing!!!**
Step 2. Cut cable to central heating pump (leaving enough length to reach where you will mount the relay if possible).
Step 3. On the pump side, strip cable, connect blue to pin 1, brown to pin 8.
Step 4. Connect the other side of the cut cable; blue to pin 4 and brown to pin 5 of the relay.
Step 5. Run new cable from a nearby spur (probably for central heating), and connect to pins 3 and 6 as per the diagram.

Step 6. Fit cylinder stat close to top of cylinder (about 12 inches from top).
Step 7. Run cable to from stat and wire to coil of relay as per diagram. (pins also denoted A1 and A2).

Using an Attic Dump Radiator

Sometimes it is not possible to disable summer valves and interfere with zoned heating, in these instances a dump radiator can be plumbed in via the solar loop. This system uses a thermostatic valve which diverts heat to the attic radiator on the return side of solar loop if the cylinder temperature reaches 60 C or greater. The circuit tends to keep the cylinder temperature to between 60 and 65C in practice. However some looses occur because the valve does not seal completely at lower temperatures.



The most exposed part of the circuit is the ESBE mixing valve, this valve is rated to operate continuously at 90C. Once the radiator is large enough to dump the maximum amount of heat generated by the panel into a hot attic space then this is a very elegant way of eliminating the possibility of overheating during normal pumped operation.The control part of the ESBE mixing valve consists of a wax plug which expands with heat. If the valve is overheated, this wax plug deforms. Afterwards the valve will probably continue to control (based on the level of overheat it was exposed to), albeit its settings will be distorted and it will in fact control to a higher temperature. Most importantly because the valve is made of brass and uses compression fittings will not leak if it is exposed to high temperature water (>90C), however steam is harder to seal against.

It is important to use a thermostatic valve that does not have an overheat cut-off. This prevents the pump trying to pump against a closed valve should the radiator and cylinder not be able to dump sufficient heat to keep the output (mixed) temperature (of the valve) to (just over) 60C.

1/2" ESBE valve without overheat cut-off - VTA312 - 31050200

The NRV (Non Return Valve - flap type) 1 meter above the mixing valve is to help force all expansion (in the event of a power failure and the system steaming up) through the coil of the cylinder. However there is also a NRV within the pumping station so this is extra protection for the mixing valve. Flap Type NRVs do not contain any plastic and springs and are more reliable long term particularly in working conditions that may include periodic exposure to high temperatures. They must however be faced arrow pointing up or horizontally to work correctly.

Mechanical Overheat	Qty
ESBE thermostatic Valve (VTA312 - 31050200)	1.00
½" 312	4.00
½" Flap type NRV	1.00
½" 311 (to fit NRV)	2.00
1/2" 318 Equal Tee	1.00
1/2" Compression to 1/2" BSP converter 340	4.00
Radiator 7500 BTU (for 2kW output)	1.00

Power Output / Sizing the attic dump radiator

When radiators are sold, their output is generally described with a temperature difference between the room and the radiator of 50C. If the radiator is mounted in a hot attic it will run much hotter to get rid of the same amount of heat. Normally a large bedroom radiator of 7500 BTU (2000 W) is sufficient to protect a 6 meter flat plate panel.

Replacing the Cylinder

It is common necessary to replace the cylinder when installing a solar system. A pressurised cylinder should only be filled by a competent person. A pressurised cylinder incorrectly connected has the energy potential to destroy a house.

Steps

1. Ensure that the boiler and circulation pump cannot turn on. This can be achieved by switching off at the heating spur, or removing the spur fuse.

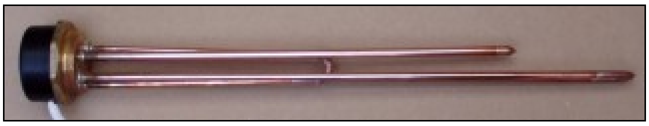
2. Ensure that the heating system is drained down to below the level of the heating coil. To help prevent airlock problems after refilling the heating system, drape the drain hose over a door, leaving the end of the hose higher that the downstairs radiators, this keeps the inert water in the downstairs radiators and removes some potential for air-locking when the system is being re-filled. Consideration can also be given to freezing the heating pipework to the cylinder.

Check the cylinder and both coils for errant pieces of foam before connecting up.

Immersion heater control

The immersion heater is normally pre-fitted to the cylinder. All heaters are factory pre-wired with a 1 meter long heat resistant 4 core cable, ensure that all connections are tight before switching on.

The thermostat is wired through the neutral, the brown wire goes to the bath element, and the black wire goes to the sink element. It is very important to ensure that the heater is earthed correctly.



With the cylinder full of water, heat the cylinder to 60C via the immersion heater or central heating system. Adjust the thermostat so that it just turns off at 60C.

Anti-Legionella. Normally an immersion heater timer is wired in front of the Sink/Bath Switch, so that this can be used to provided a timed source of heat. This is a SEI requirement.

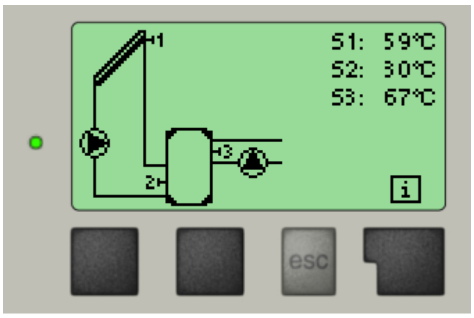
Anti-Frost settings

There are two ways to protect against solar panel pipes freezing. The first way is to use the controller function. However this can only be used in some circumstances when using heat pipe solar collectors. The TDC3 controller has two anti-frost settings, below which the first turns the pump on for 1 minute every hour. (e.g. at 2C), if the manifold temperature drops below a second setting (e.g. 1C) then the controller runs the pump continuously until the temperature recovers. This is adequate most of the time, however in rural areas where freezing conditions may coincide with a power outage, this system can leave a solar panel exposed to freezing, it is a small risk and the consequences are not catastrophic if pipe work to the panel were to fail. Most likely the leak would be outside the building and because the system is closed only a couple of litres would leak.

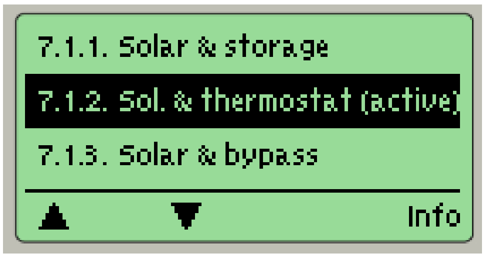
The other alternative is to fill the system with an Anti-freeze mix, this is necessary if a flat plate collector or primary fluid vacuum tube panel is used.

Installing the TDC 3 controller

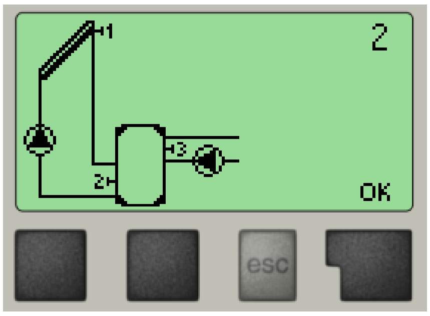
Wire the controller as per the instructions below. The terminals are spring loaded to prevent over tightening. Note: A small flat head screwdriver is required to access terminals.



Use left buttons to access menu. Choose Special functions

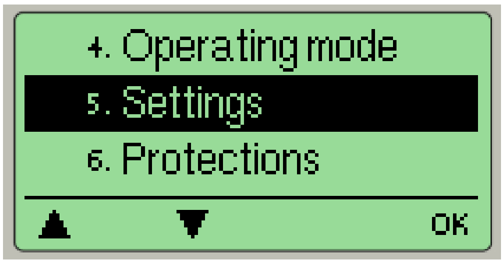


Select Sol. & Thermostat (active)



Choose **OK**

Next return to main menu and choose "Settings"



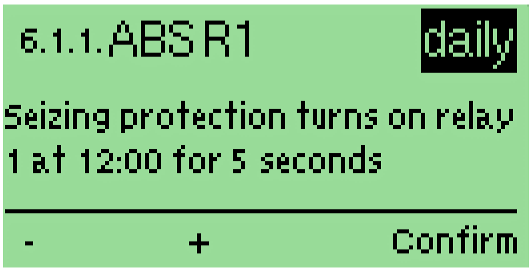
Program the following settings

TminS1 15°C
TmaxS1 70 °C
ΔTR1 16°C
Tset S3 65°C
Hysteresis -5°C

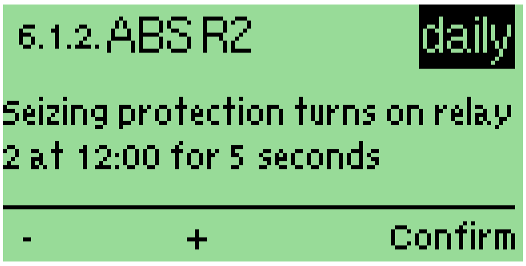
Operation: The solar controller will keep the panel in operation until S2 (bottom sensor) reaches 70C, when the solar panel will turn off.

However because we choose the thermostat function and set this at 65C, when S3 reaches 65C, relay R2 on the controller is turned on which is connected via a relay to the central heating pump or a second pump on the central heating line.

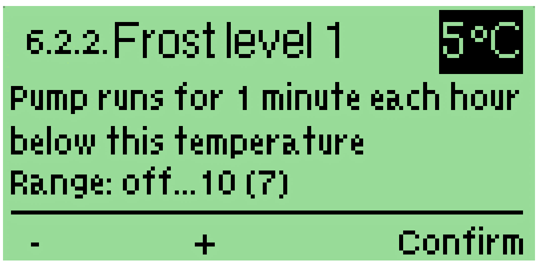
The hysteresis set at –5C will keep relay 2 turned on until the temperature measured at S3 reduces to 60C. (i.e. Tset S3 + hysteresis). It is important to set the hysteresis to a negative value, a positive value will tell the controller that you are trying to heat the cylinder with an external heat source and it will try to turn off relay R2 at 70C.

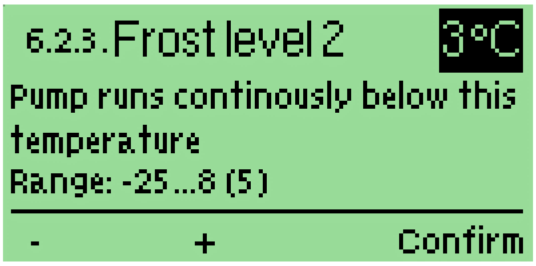


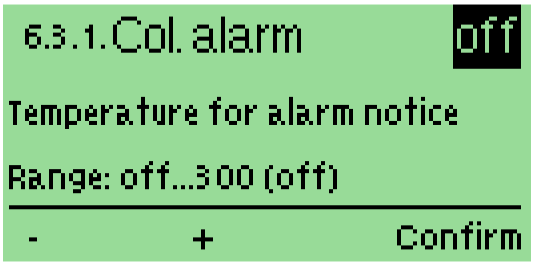
This prevents the pump on Relay 1 from seizing should no solar be available for several months.



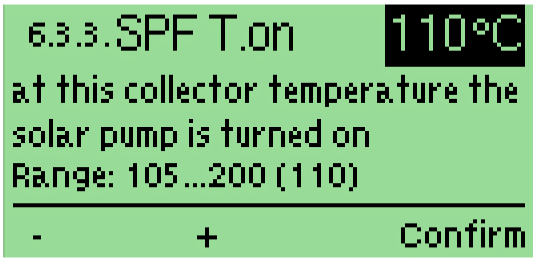
Anti-Seizing protection for overheat pump. This is far more important as it is likely that this pump will only run during the summer.

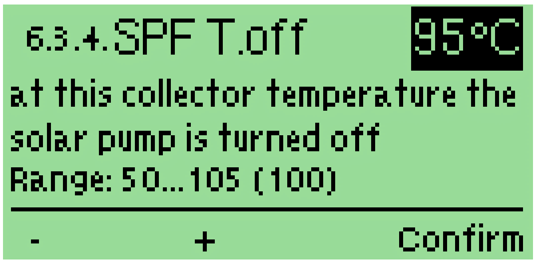


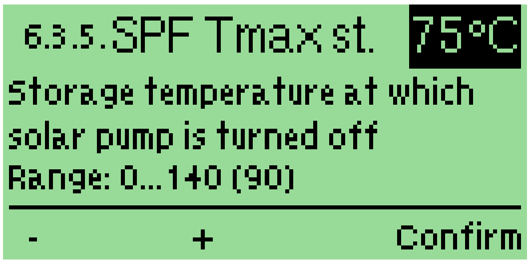




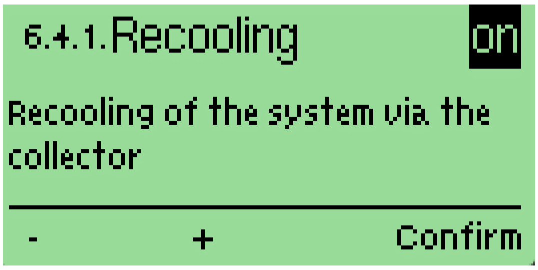
This function is very important for systems without heat dumps. Basically it is used to keep the solar panel below a preset (safe) temperature, if the panel goes above the preset temperature then the solar pump is activated and the water in the panel is circulated unit the panel drops below the reset temperature. This continues until a second maximum cylinder temperature is reached (e.g. 85C with a mixing valve), and at this point the SPF function is deactivated to protect the cylinder.

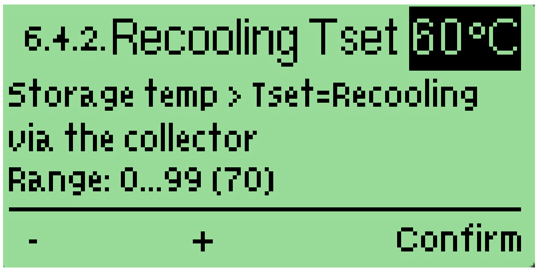






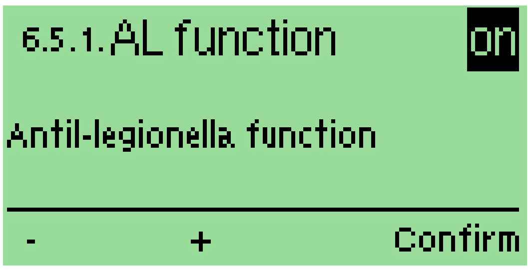
If a heat dump is used, then this function can be disabled. However if it is used when using a system without a heat dump then the “re-cooling” function should be set to ON. The recool turns the solar pump on when the panel temperature is 20C cooler than the cylinder and continues until it reaches Tset.

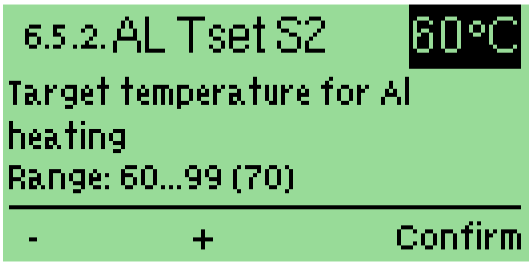


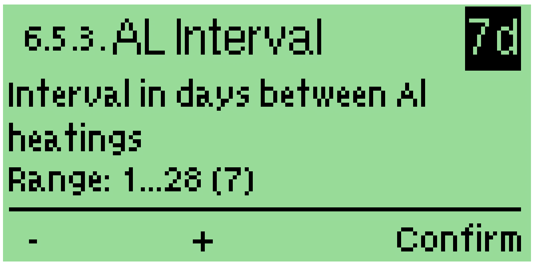


Anti-legionalla

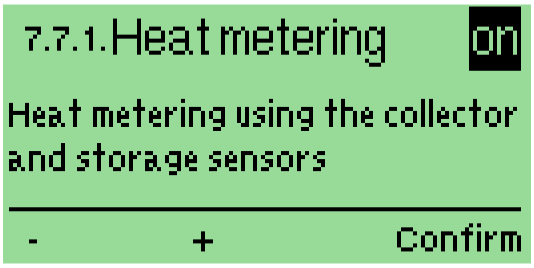
This is purely an Anti-legionalla function which relies on solar energy to heat the cylinder to 60C. If there is not sufficient solar energy to do so, then it reverts to normal control.

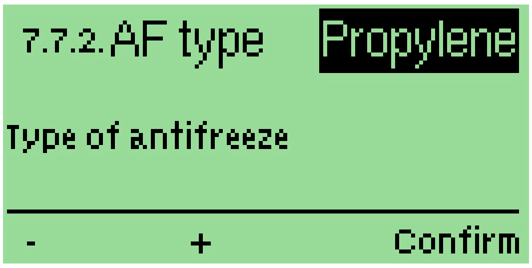


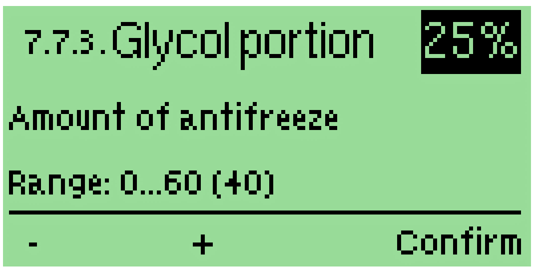




This allows the customer to estimate how much energy the solar panel has produced.







(change if Anti-freeze concentration is different).

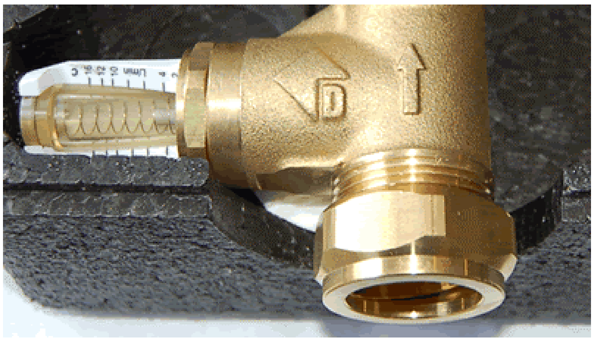
7.7.4. Flow rate **240l/h**

nominal flow rate of the system

Range: 10...5000 (500)

-    +   Confirm

(240 Litres per hour is the equivalent of 4 litres per minute). When running the pump at full speed, read flow rate on pump-station indicator.



7.7.5. ΔT offset **0%**

Heat metering ΔT correction factor

Range: -50...50 (0)

-    +   Confirm

Starting aid for vacuum tubes.

7.8.1. Starting aid **on**

Function for vacuum tubes

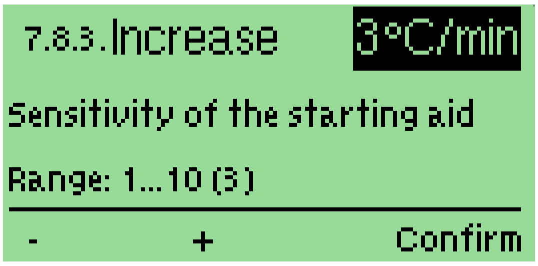
-    +   Confirm

7.8.2. Circulation time **5s**

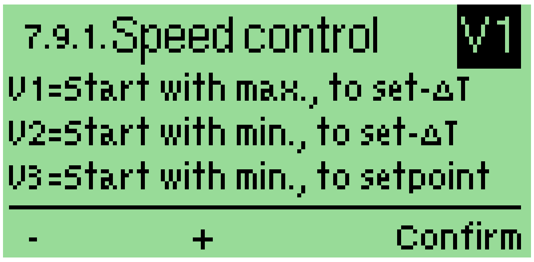
Circulation time of the starting aid

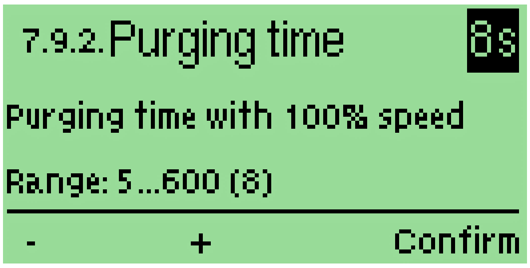
Range: 2...30 (5)

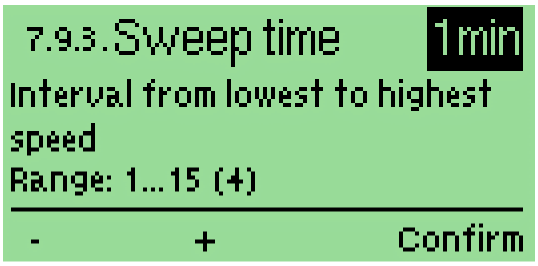
-    +   Confirm

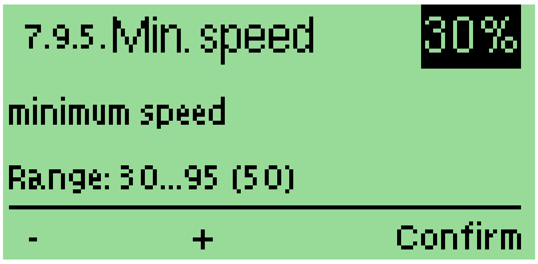


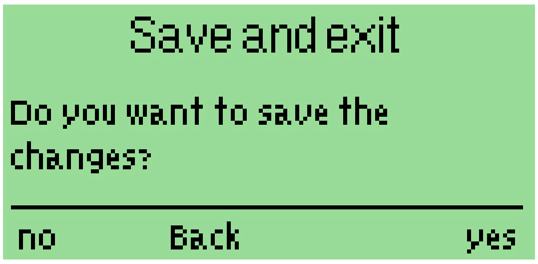
This is important because it matches the pump speed to the available solar energy. This keeps a steady “delta-T” and avoids the inefficiencies the inevitably result because of the delay of the sensor in reading actual panel temperature. (i.e. panel over-heats before pump is turned on and over-cools before solar pump is turned off)





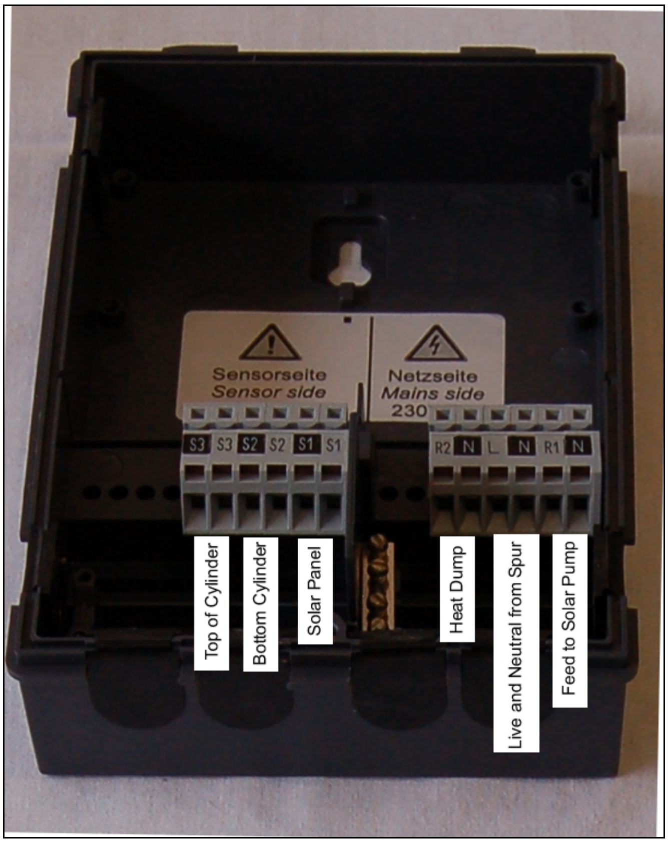






Wiring the controller.

A 3Amp switched fused spur should be used to connect mains to the controller. Internally the controller should be wired as per the picture below.



Lightening Protection
If the panel is above the roof line, it should be protected from lightening (e.g. on flat roofs). Run a 16mm earth cable to an earth rod (or to an existing TV aerial protection). Cable should run outside the building only.

Filling the System

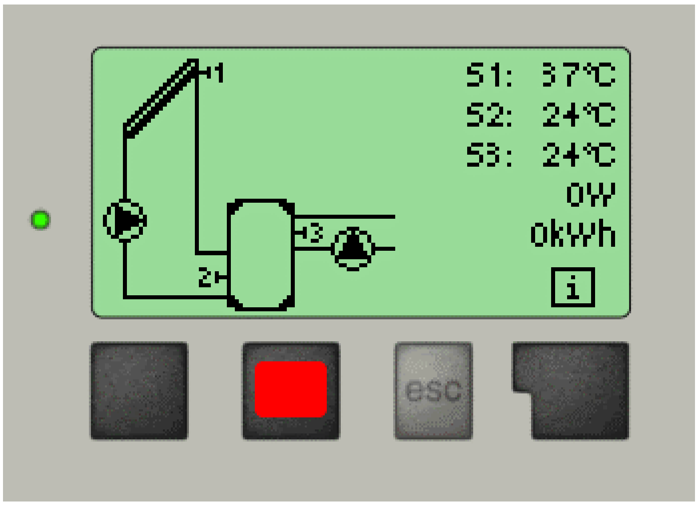
A pressurising pump is used to fill the system, this circulates the water through the system expelling the air. However because this system uses a mixture of 10mm and 22mm and 28mm (in the cylinder coil) pipe-work air can get trapped. We have found that when circulating the water it is useful to crack the nut on the tank fitting of the solar coil, wait until the hissing stops and re-tighten.

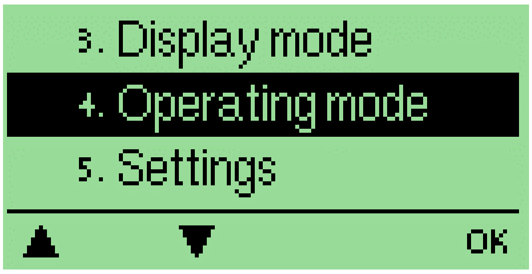
The second place air tends to get trapped in at the manifold. Again crack and re-tighten the downstream manifold nut. Running the pipework up the roof also tends to help expel air more easily.

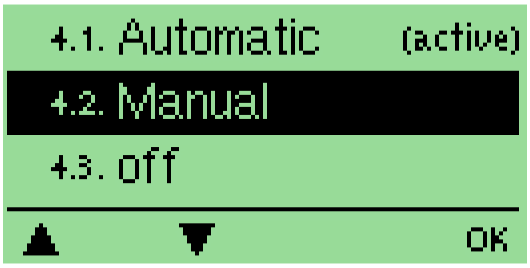
Some single line pump stations can also be filled in the reverse direction. Swap the fill and drain hoses, and close the isolating valve above the pump. Water is then flushed in the opposite direction. This can help get rid of stubborn air pockets. Also pressurising the system to 5 bar (or greater) squeezes the air bubbles and are easier to flush out of the system. (Partially close the drain valve to increase the filling pressure).

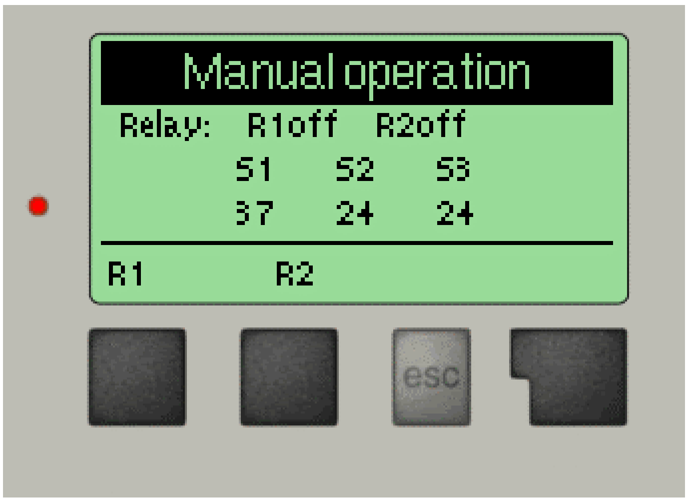
Commissioning

Using the front buttons as shown below the outputs can be turned on manually to check system is free of air.









Earth Bonding
Bond Copper pipework from the solar panel to an earth point in hot-press.

Tools Required
Pipe cutters.
Plumbing spanners
Adjustable spanner
10mm & 14mm Sockets
Terminal Screwdriver (small flathead)
Normal Screwdrivers
Wire cutters
Voltmeter
Stanley Knife
Drill / Masonry drill bits
Extension lead
Inspection Light
6mm & 22mm diamond tipped drill bit.

Units of Energy

Energy is measured in Joules.

Units of Power

Power is normally measured in Watts.

Power and Energy

Energy used is the amount of power acting multiplied by the amount of time.

1 Watt of Power acting for one second produces 1 Joule.

A Watt is also called a Joule-second.

1 kWhr is therefore 1000 Watts acting for 1 hour (3600 seconds), or in other words

1 kWhr = 1000 x 3600 = 3,600,000 Joules

Energy and Water

About 4200 Joules are required to heat 1 litre of water by 1 degree Centigrade.

Example 1

1 litre of water is heated with a 2kW kettle from 10C to 100C.

2kW means that 2000J are supplied every second.

To raise 1 litre by 90C 378,000J are needed, (4200 x 1 x 90)

This means that a 2kW kettle needs 189 seconds to boil the litre of water.

Example 2

A 30 gallon (130 litre) cylinder is heated from 10C to 60C.

The energy required is;

50C x 4200 x 130 = 27,300,000 J

This is a very large number that doesn't mean an awful lot, so to convert this to kWhr, simply divide by 3,600,000

= 7.58 kWhrs

a 3kW immersion heater would therefore require 2½ hours to heat the cylinder. 7.58 divided by 3.

Shortcut to quickly work out energy required to heat water.

If we divide 4200 by 3,600,000J we can get a factor to work out how much energy is required in kWhrs.

0.001166

A simple formula now exists

Volume x Change in Temperature x 0.001166 = Energy required in kWhr

Example 3

How much energy is used to heat a 200 litre cylinder from 10C to 57C?

Change in Temperature = 47
Volume = 200

Answer= 200 x 47 x 0.001166

= 10.96 kWhr

So a 18kW boiler (60,000 BTU) will be capable of heating this water in

36½ minutes

or a 3kW immersion would take

3 hours 39 minutes

Example 4

A typical daily shower uses 30 litres of water at 39C. If the incoming mains water is at 10C, how much energy is used over the whole year?

Change in temperature = 29C
Volume = 365 x 30 = 10950

Energy in kWhrs = 29 x 10950 x 0.001166
= 370 kWhr

Example 5

An 130 litre (30 gallon) uninsulated cylinder in a “hot press” is heated by the central heating every evening from 20C to 60C. It cools overnight to 20C, so that the central heating is required in the morning to re-heat this water. How much energy is wasted by overnight cooling when the heating is used for 300 days per year?

Change in Temperature = 40C
Volume = 130 x 300

Energy = 40 x 130 x 300 x 0.001166

= 1819 kWhrs.

(note that this is almost the annual output of a solar panel).

Note: Replacing a cylinder with a properly insulated cylinder (with lagged pipework) can achieve the similar energy savings as the installation of a solar panel.

Units of Energy and Oil.

Heating oil contains about 10.5kWhrs per litre.

1 litre of oil when burned produced 3Kg of CO_2.

Example 6

In the example above, 1819 kWhrs would equate to 173 litres of oil. But only if burned in a 100% efficient boiler.

An typical efficiency might be typically 80%, so in actual fact the litre of oil is only giving about 8.4kWhrs. So the cylinder in example 5 is actually wasting 216 litres of oil.

In CO_2 terms this equates to 649 kg

In actual fact, the saving would be higher, normally the complete house is heated in the mornings for at least an extra hour, so that there is sufficient hot water generated for morning showers.

Water Content of Copper Tubes

Nominal Size (mm)	Water Content per Meter (Litres)
8	0.036
10	0.055
15	0.145
22	0.320
28	0.539
35	0.835
42	1.232

Example 7

A solar panel is installed with a total of 30 meters of pipework (flow and return). Calculate the volume of heat transfer fluid contained in the pipework. Calculate for 10mm, 15mm and 22mm.

Secondly, if the pipework cools from 50◦C to 20◦C at night, calculate the energy lost each night the solar panel is running. Assume a 20% Polypropylene Glycol mix.

Thirdly, assume that the solar panel runs 300 days per year and produces 2000kWhr. What is the percentage efficiency drop caused by the volume of liquid in the pipework cooling. Calculate for 10mm, 15mm and 22mm.

Answer

Nominal Size (mm)	Water Content per Meter (Litres)	Content in 30 Meters
10	0.055	1.65
15	0.145	4.35
22	0.320	9.60

Specific Heat capacity of water = 4200 J per litre per 1˚C. Polypropylene Glycol specific heat capacity is 3590 J per litre per 1˚C. This is close enough to be ignored.

Fluid in pipework cools by 30˚C.

Hence Energy in Joules =

30 x 4200 x Volume in pipe.

10mm pipe = 30 x 1.65 x 0.001166= 0.057 kWhr per day
15mm pipe = 30 x 4.35 x 0.001166 = 0.152 kWhr per day
22mm pipe = 30 x 9.60 x 0.001166 = 0.336 kWhr per day

If the panel runs for 300 days per year and creates 2000 kWhrs of energy over the year, then

for
10mm pipe: 0.057 kWhrs per day x 300 = 17.1 kWhrs
15mm pipe: 0.152 kWhrs per day x 300 = 45.6 kWhrs

22mm pipe: 0.336 kWhrs per day x 300 = 100.8 kWhrs

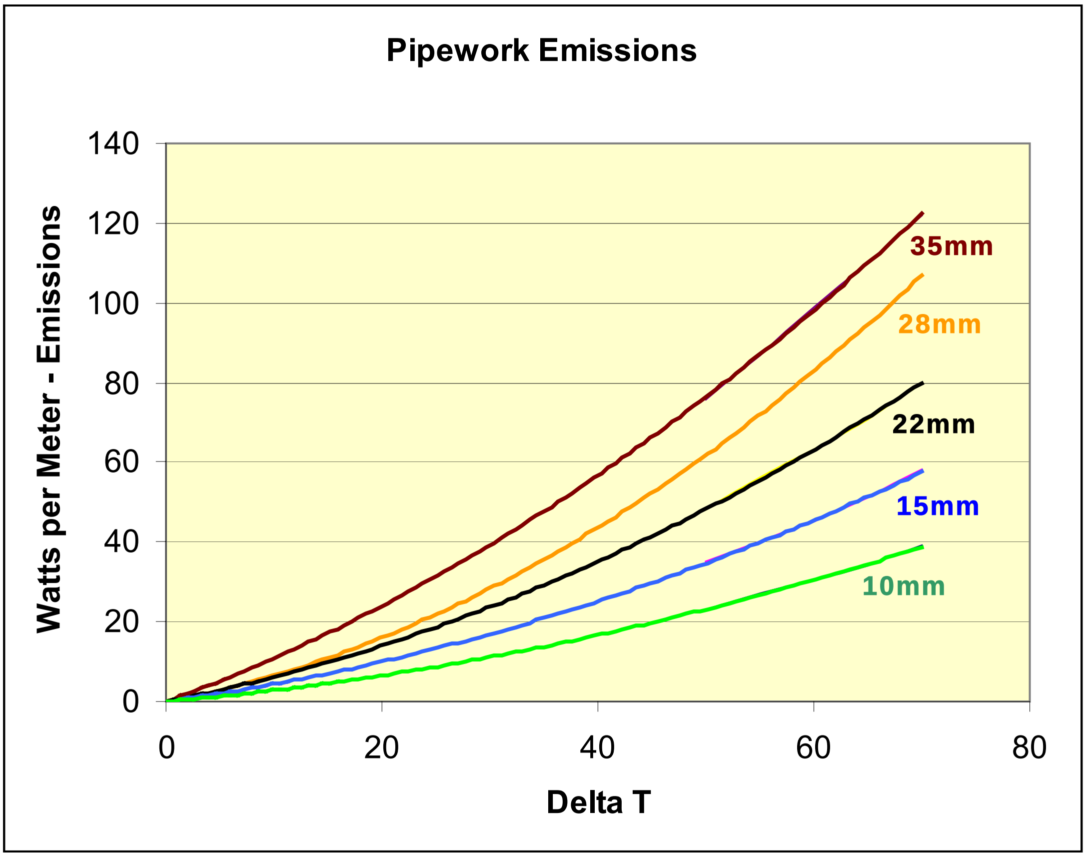
This equates to an efficiency drop as follows

$\frac{17.1}{2000} \times 100\% = 0.855\%$ (10mm pipe)

$\frac{45.6}{2000} \times 100\% = 2.28\%$ (15mm pipe)

$\frac{100.8}{2000} \times 100\% = 5.04\%$ (22mm pipe)

Pipework Emissions (horizontal pipe)



Pipework Emissions in Watts / Meter (horizontal)

	Temperature Difference °C						
Pipe Size	**50**	**55**	**56**	**59**	**61**	**65**	**70**
8	19	21	22	24	25	27	31
10	23	27	28	30	31	34	39

15	35	40	41	44	46	51	58
22	40	56	57	61	64	71	80
28	64	72	74	79	82	91	110
35	76	87	89	96	101	110	122

Pipe Layout Factors

These figures are for single horizontal pipes, for double pipes, or vertical rises multiple the numbers above by the following factors.

	Factor
Single Horizontal	1.00
Double Horizontal	0.90
Vertical up to 15mm	0.75
Vertical 22mm and higher.	0.80

Example 8.

Assume a boiler plumbed in 22mm horizontal copper pipe, with a 6 meter flow and a 6 meter return from the house. The pipework is un-insulated, calculate pipework emissions, if the flow temperature = 71˚C, the return temperature is 60˚C and the garage is 10˚C. Assume that the pipes are not running alongside each other.

Assume that the heating is on for 8 hours per day, 300 days per year, calculate annual cost in oil and in additional CO2 emissions?

Answer:

With the garage at 10˚C and the flow pipe of 71˚C, this gives a Δt of 61˚C, looking at the table above, this equates to 64 Watts per meter. Therefore 6 meters emits 384 Watts, similarly the return pipe at 60˚C gives a Δt of 50˚C, and looking at the table above, this gives 40 Watts per meter, therefore 6 meters emits 240 Watts.

Adding both these values together and we get a total of 624 Watts (2100 BTUs).

If the heating is running for 8 hours per day for 300 days per year. This equates to

624 Watt x 8 hours = 4.992 kWhrs per day or

1497.6 kWhrs per year.

In terms of oil, assuming a system efficiency of 76%, we get 8kWhrs of energy from 1 litre of oil.

Hence 187.2 litres of oil per year is wasted.

Secondly, burning 1 litre of oil releases about 3kg of CO2, so the CO2 emissions are 561 kg CO2.