In my overview of solar heating last month, we saw that the immediate financial return of installing solar water heating is disappointing: something like 2% pa if the fuel saved is gas, and about 6% pa if the fuel saved is electricity. But even if you are building now, solar water heating still warrants consideration. It seems likely that the price of gas and electricity will be increasing for many years to come, and the price of retrofitting a system is about 30% more than installing in new build. Moreover, a solar system appreciably cuts carbon emissions, and this can improve the Energy Performance Certificate of your house.

In 2010, the building regulations are due to be revised, reducing the amount of carbon emissions allowed. The government has said that the Target Emissions Rate (TER) will probably be reduced by 25% – and in 2013 by 56%. Solar water heating will become a common feature of new build.

The first solar water heating systems were produced in California at the end of the Nineteenth century, and there was renewed interest in the technology after the oil shocks of the Seventies. So the technology is mature – but that is not to say that it is well understood by the average plumber.

The basics are simple enough. The energy of sunshine, or merely daylight, is harvested in a solar collector and transferred to the hot water store. But there are many variations in the way this is achieved.

A practical system needs to avoid:

- Freezing – due to cold weather. (Freezing is possible even with air temperatures above zero!)
- Scalding – due to solar hot water becoming dangerously hot.
- Boiling – possible in hot weather with no water draw-off.
- Cooling – in a poorly designed thermosiphonic system, the collector might cool the water at night.
- Scaling – a potential problem in hard water areas.

Collectors

There are three types of collector in common use:

- Flat plate collectors – the most popular.
- Tube collectors – more expensive, but more efficient in some circumstances.
- Unglazed plastic panels – cheap.

Flat plate collectors

A flat plate collector has a metal sheet (aluminium, steel or copper) with a black surface to absorb the solar radiation. In good thermal contact with the underside is copper pipework through which flows the solar fluid (eg, water with antifreeze). The fluid collects the heat and transfers it to the solar cylinder.
To attain high temperatures, heat losses must be minimised. So the underside of
the panel is insulated with about 5 cm of mineral wool, and the topside is insulated
by an air gap beneath single or double glazing. (Low iron glass is preferable – being
more transparent than ordinary glass, it allows more solar energy to reach the
absorber.)
The absorber’s surface should have:

- High absorbance
  – to absorb the maximum amount of solar energy.
- Low emissivity
  – to minimise the amount of energy radiating outwards from the warm
    absorber (as infra-red radiation).

A variety of high-tech selective coatings are in use to give both high absorbance (eg,
95%) and low emissivity (eg, 5%).

*Tube collectors*

A tube collector has an array of glass tubes, the tubes being a few centimetres in
diameter and a metre or more long. Although the inner workings of the tubes vary in
design, the distinctive feature is that the tubes are partially evacuated. As in a
‘Thermos’ flask, the vacuum makes for excellent insulation, so tube collectors lose
less of the heat they absorb. This is especially efficacious when there is a large
temperature difference between the absorber and outside (eg, when the weather is
cold or the water temperature high).

Inside each tube is a selectively coated absorber, and these are of two types:

- A long flat metal fin, analogous to the plate of a flat plate collector.
- A long cylinder of metal (or glass).

The glass tubes are connected to a manifold along the top of the collector, and
there are two ways of transferring the heat gained by an absorber to the manifold.

- Solar fluid circulation
  The flow and return pipes may be in the form of a long loop down the tube;
or they may be in the form of two concentric pipes down the middle of the
tube, the flow in the inner pipe and the return in the outer.

- Heat tube.
  This is an ingenious and effective way of transferring heat.
  A heat tube consists of a sealed tube, at the bottom of which is some liquid
  with a low boiling point, eg, an alcohol, or water under a partial vacuum.
  When the heat tube becomes warm the liquid boils. The vapour rises to the
top of the tube, to the manifold where solar fluid circulates. The vapour is
cooled by the solar fluid, and condenses, thereby releasing its latent heat to
the solar fluid. The condensed liquid runs back, under the influence of
gravity, towards the bottom of the tube. In this way, a continuous cycle of
vaporisation/condensation transfers heat up to the manifold.
  The process is similar to what happens in a heat pump, except that no
electricity is required.
**Unglazed plastic panels**

Perhaps surprisingly, bare plastic panels are the most efficient collectors of them all – for small temperature rises. So use these cheap panels for heating your swimming pool.

**Heat transfer systems**

The heat gathered at a collector needs to be transferred to the solar store, either by a direct system, or, more commonly, be an indirect one.

- **Direct system**
  
  In this simple system, the solar fluid is mains water. This flows from the solar store, through the collector, and back to the solar store; then eventually to a tap.

- **Indirect system**

  The solar fluid (usually water with antifreeze) circulates through the collector and then through a heat exchanger, which is usually a coiled pipe inside the hot water store. The domestic hot water is warmed by the heat exchanger, and is kept entirely separate from the solar fluid.

  The direct method is the more efficient, but it cannot be used in a hard water area because of the build up of scale at high temperatures.

  The use of a heat exchanger in the indirect method results in, maybe, 10% – 20% less heat being gained by the domestic hot water. But as only a fixed amount of water is being circulated, scale build up is avoided. Most importantly, the indirect method allows antifreeze to be used. (Though as we shall see, there are other ways to counter the problem of freezing.)

**Circulation**

Whether a direct or indirect system is used, the solar fluid moves either by natural convection (a thermosyphonic system) or by the use of a pump.

**Thermosyphonic system**

In a thermosyphonic system, the pipework is designed so that natural convection causes the solar fluid to flow between the collector and the solar store (direct system) or the heat exchanger (indirect system).

A convection circulation is set up when water is heated in the collector. The water expands and, being less dense, it tends to rise. With a direct system, wide-bore pipework between the top of the collector and the top of the solar store allows the water to rise into the store. Cooler water flows back from the bottom of the store along pipework to the bottom of the collector. For this convection flow to occur, the solar store needs to be level with, or preferably above, the collector; and preferably the pipework should everywhere be sloping upwards from the collector to the store. (With an indirect system, of course, the circulation is between the collector and the heat exchange coil.)
If the store (or heat exchanger) is not entirely above the collector, unwanted
night-time cooling of the solar water might occur – the flow goes into reverse. This
can be prevented by including a one-way, check valve in the circuit.

There is much in favour of these simple systems, and worldwide they are very
popular. Visitors to Mediterranean countries will have seen many solar systems on
flat roofs, with the store on top of the collector and a siphonic flow between the two.
In the UK, collectors are usually positioned on pitched roofs, and often the store has
to be below the collector. So a pump has to be used.

**Pumped circuit**

In the UK, most solar circuits include a circulator. These are pumps which are
efficient at pumping water at low pressure, rather than pumping water to a height – in
the closed circuit found in most solar systems there is no head pressure to pump
against, only friction. (The exception is in a drain-back system – see later.)

The use of a mains-powered circulator necessitates two temperature sensors
connected to a controller, and the controller instructs the circulator when to operate.
When the temperature of the top of the collector is a few degrees (eg, 7ºC) above the
temperature of the bottom of the solar store, a ‘differential thermostat controller’
switches on the circulator.

A variation is the PV-powered circulator. Temperature sensors and a controller are
unnecessary. The stronger the sunshine, the more heat is absorbed by the collector
and, at the same time, the more electric power is available, enabling the circulator to
pump the solar fluid to the store more quickly.

**Avoiding freeze-ups**

The connecting pipework has to be well insulated to prevent heat losses, so freezing
up of the connecting pipework is unlikely to be a problem. (It should be noted that
the pipe insulation should be rubber-based rather than plastic-based, as the latter is
more likely to be degraded by the high temperatures that can be experienced in hot
weather. Similarly, copper pipework is preferable to plastic.)

Be aware that, on a clear night, the temperature of a collector can fall below zero
even when air temperatures are above zero – the temperature of the collector falls as
it radiates out energy to the night sky.

**Antifreeze**

The most common way to prevent solar fluid freezing is to use an indirect system
with antifreeze in the water. Propylene glycol is the antifreeze usually used – don’t
use poisonous, car antifreeze. (A 30:70 mix of glycol and water is typical.)

Unfortunately, glycol degrades at high temperatures, becoming acidic. So the solar
fluid should be tested occasionally, and if necessary replaced, typically after five to
ten years. Another downside is that the pump has to work harder, compared to
pumping plain water. But an indirect system with antifreeze gives a versatile system
which can be installed in a wide variety of situations.

**Drain-down system**

In this simple method, plain water is used as the solar fluid – the system is manually
drained down for wintertime. (Last month’s article had a table showing that heat
gains in wintertime are small.)
**Drain-back system**

The solar circuit includes a tank below the collector. When the pump is not in operation, water drains out of the collector and the water level in the tank rises. So if the pump is instructed to switch off in freezing weather, no damage can be done to the collector. Likewise, if the pump is switched off when the water becomes too hot, boiling is avoided.

The pipework needs to slope so that all the water in the exposed pipework and collector can drain back into the tank. (A stronger pump is required, to pump water up from the drain-back tank to the top of the collector.)

**Freeze tolerant system**

The collector has flexible pipework which is not damaged if the water freezes – eg, rubber pipe rather than copper. Also systems which use air as the solar fluid are freeze tolerant.

**Other methods**

Some other methods that may be suitable in some conditions for avoiding freeze-ups:

- **Auto pump control.**
  In freezing conditions, the pump keeps pumping to prevent the water turning to ice.

- **Auto drain-down.**
  At a near freezing temperature, a valve opens to dump the solar fluid, which is plain water. (Manual refill is required.)

- **Insulation.**
  Put an insulating cover over the collector in freezing conditions.

Next month: More about solar water heating.

FURTHER INFO:

_Tapping the Sun_  
—A Guide to Solar Water Heating  
By Chris Laughton, £8.

_Solar Water Heating_  
—A DIY Guide  
By Paul Trimby, £8.

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