SOLAR HOT WATER SYSTEMS

Radiation from the sun (normal light) can be transformed to useful heat to provide, for instance, hot water. This can be in almost all areas in the world. Copper has by far the highest thermal conductivity of any commercial metal and this factor, together with copper's good corrosion resistance and its ability to withstand high temperatures, makes it an ideal material to use for many parts of solar thermal systems.

Recently in the UK, major political support has been given to all kinds of renewable energy, including the need to support renewable heating and cooling. Correctly designed solar thermal systems have a proven track record in providing dependable hot water and space heating and, as more systems are installed and economies of scale come into play, payback periods will reduce to make them more cost-effective.

UK solar irradiation is relatively low in intensity for long periods, ranging on average from about 2.4kWh/m^2 per day in Scotland and the North of England to 3.0kWh/m^2 per day in the South West.

Irradiance also varies from a minimum of about 60W/m^2 at the winter solstice to about 1000W/m^2 at the summer solstice. It is often intermittent during the day because of cloud cover and also varies in intensity through the day from zero at sunrise, rising to a maximum at noon and back to zero at sunset.

During the summer solar energy can meet the entire demand for domestic hot water economically, but in the winter some form of back-up heating may be required. Overall efficiency in a solar thermal system will be maximised if the collector and piping system have the correct water capacity required to carry the collected heat energy to the storage cylinder. If the collector has a high thermal capacity (due to a large water volume), then it will be relatively slow to heat up.

An appropriately-sized solar collector will increase the efficiency with which energy is captured, especially on cloudy days.

A flow rate of between 0.01 and 0.02kg/s for each square metre of collector area should be used when choosing tube diameters for the circulation piping. Temperatures in the collector can vary from about -20°C at night in winter to +350°C during stagnation periods (when the heat transfer fluid is not circulating, even though the panel is fully irradiated). Therefore, only materials like copper, that can withstand this temperature range and the associated thermal shocks without damage, should be used for the installation.

Types of solar collector

There are a number of designs of collector, the flat-plate type being the simplest, see Figure 1. These consist of a metal heat-absorber plate, the surface of which is blackened to make it more efficient in absorbing solar energy and to reduce the emission at higher temperatures. Tubes are attached to the absorber plate to enable heat transfer. The heat transfer is usually by means of water (with inhibitors), for systems of the drain-back concept, or of a food-grade glycol-and-water antifreeze solution, which is circulated to carry heat from the collector plate to the storage vessel.

One or two layers of glass or transparent plastic, separated by an air space, are incorporated above the plate to trap the energy. This air space reduces convective and conductive heat losses back to the atmosphere. The glazing also minimises heat re-radiation from the collector.

Insulating the back and sides of the collector, as well as the pipes leading to and from the cylinder, further reduces heat losses. Ideally, the collector will be mounted so that the glass absorber surface is south facing but, even if it is west facing, it will still perform at 80% of the ideal, provided it is angled between 30° and 60°. Instantaneous efficiencies of solar collectors can be as high as 80% when they are operating at close to the ambient (surrounding air) temperature.

In a typical domestic installation in Northern Europe 1.0 to 1.5m^2 of net flat-plate collector area is used per person for heating domestic hot water.

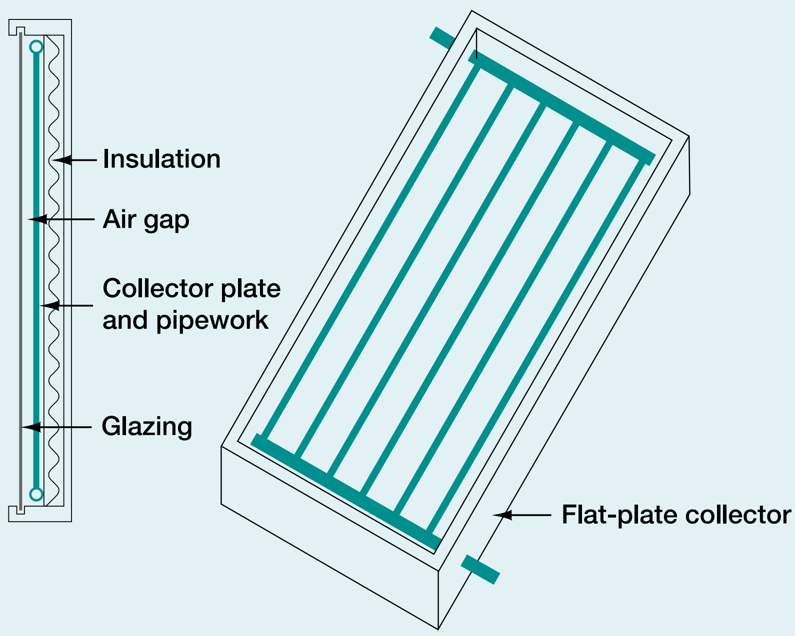

Figure 1 – Flat-plate collector

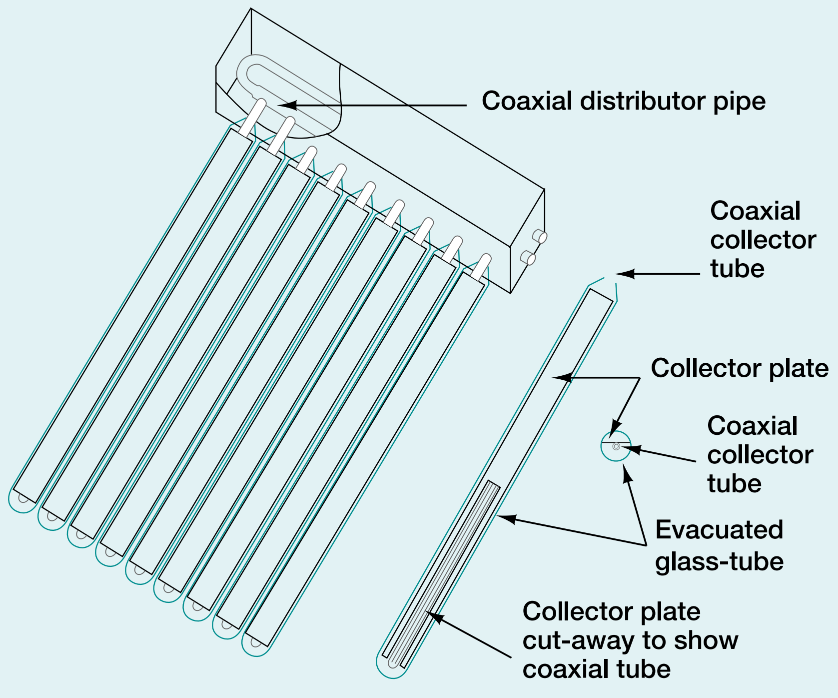

Figure 2 – One type of glass-tube collector

Evacuated glass-tube collectors are also available, see *Figure 2*. These comprise a coaxial circulator tube (a tube within a tube) attached to a collector plate fitted within a sealed glass tube. The outermost part of this glass tube has much of the air removed to create a partial vacuum, which reduces heat losses and makes tube collectors more efficient at the higher temperatures. For the typical temperature to heat domestic hot water, the annual efficiencies are comparable to flat-plate collectors. Individual tube collectors can be connected to a coaxial distributor pipe by means of push-fit or threaded joints. This type of joint enables the tubes to be rotated to optimise the angle of the collector plates with the sun. This means that glass-tube collectors can be fitted either to sloping roofs or horizontally or vertically on roofs or walls and still have their collector plates aligned with the sun for maximum efficiency.

A typical system

A typical solar domestic hot water system consists of an area of solar collectors, a piping circulation system, controls and water storage, see Figure 3. In southern European countries the collectors can be sited below the storage cylinder (as the potential for freezing problems is low), then the heat can be carried from the collectors by natural convection, see Figure 4. However, in Northern European areas the collector panel or tube will be roof-mounted and so will be above the storage cylinder. As a result, a circulator pump and temperature sensing controls to turn the pump on and off will be required. For fully-filled systems a check valve will also be needed to prevent circulation from the storage cylinder when it is hotter than the collector. This will prevent the cylinder from being cooled due to natural convection when the pump is not running. This check valve is not required for drain-back systems.

When water is heated it will expand. It is especially important to cater for this expansion in a solar heated system as, under certain climatic conditions, the heat transfer fluid may boil and vaporise. This situation can be addressed by installing a vented system (one where an open vent pipe discharges into a header cistern) or, more usually, a sealed system with an expansion vessel and safety valve. This means of accommodating expansion is not required for drain-back systems as they have a built-in reservoir and the systems are "drained" at the point that overheating may occur. The copper absorber is then left to stagnate, a state that it can easily withstand.

Hot water storage needs to be carefully considered. Between 30 and 50 litres of hot water (stored at 65°C) daily per person will normally be sufficient, with 20 to 40 litres of pre-heat storage per square metre of collector area. Storage is usually by means of a single or dual-coil vented or unvented domestic hot water cylinder. The lower coil is used for the solar circuit and the bottom half of the cylinder is the pre-heat store, whilst the upper coil is heated by a boiler

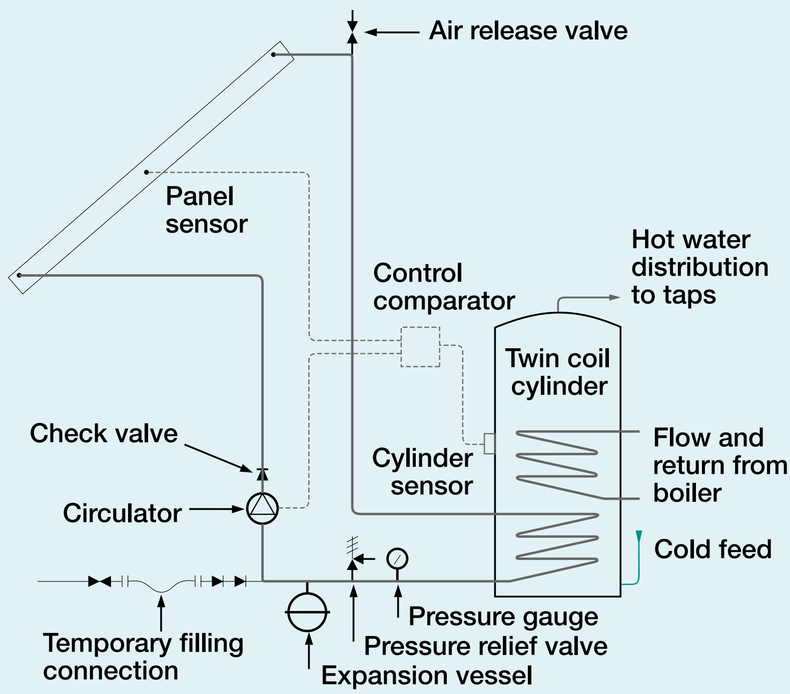

Figure 3 – Solar hot water system

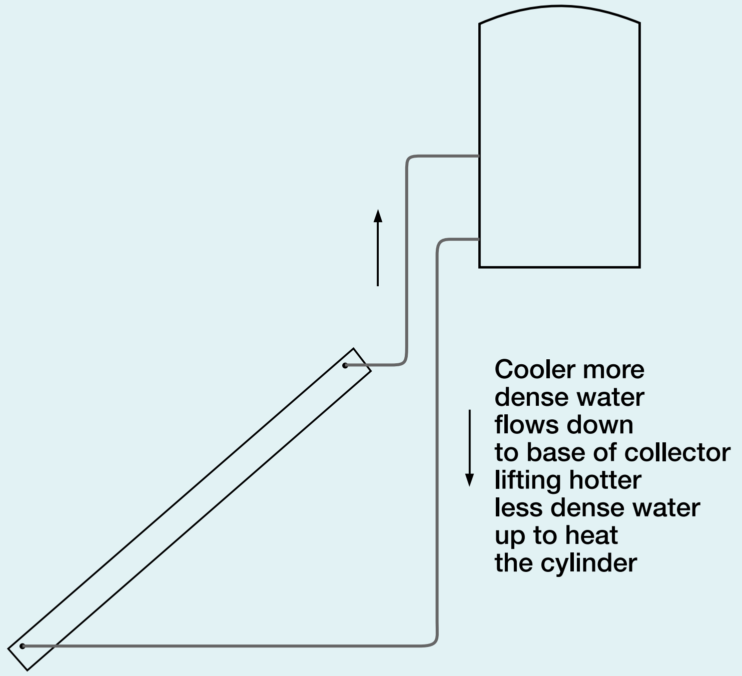

Figure 4 – Natural convection with collector below storage

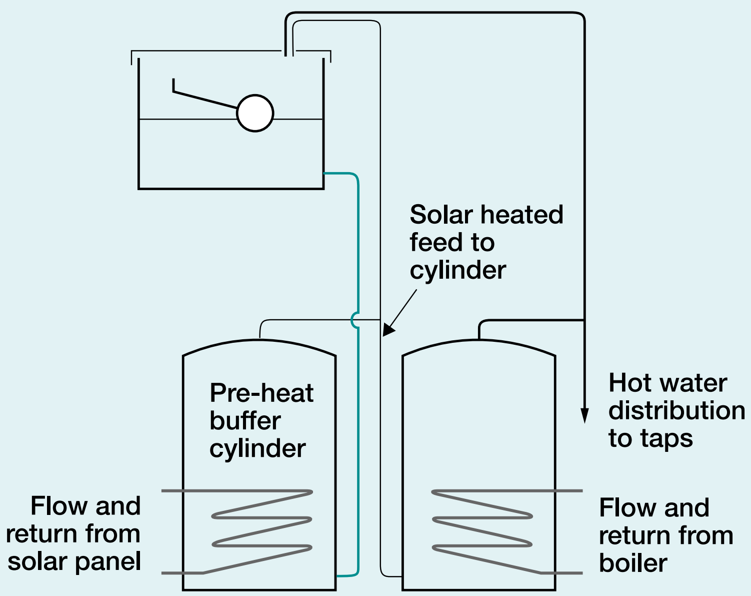

Figure 5 – Twin cylinder installation

or immersion. Alternatively, especially when incorporating a solar system into an existing hot water installation, two indirect cylinders can be used. With this arrangement the solar heated cylinder feeds pre-heated water to the second cylinder or to a back-up boiler from where hot water (with auxiliary heat supplied by the boiler if necessary) is fed to the discharge points, see *Figure 5*.

Pump control

Pump control is achieved by temperature sensors, attached to the solar collector and storage cylinder, and a comparator circuit, see again Figure 3. This measures and compares the temperature of the collector with the temperature of the solar storage cylinder. When the collector is sufficiently hot (say +6°C above the cylinder temperature) the pump will start and will continue to run until the collector temperature cools or, in case of drain-back, there is no further useful contribution from the collector to the storage cylinder.

Brian Curry: 2007.