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Copper Solar Thermal Systems

UK Copper Board

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Introduction

This publication outlines the processes required to design and install copper solar thermal installations. It is not intended to be a designer's manual nor to be an alternative to an approved training course run by a recognised awarding body, e.g. City and Guilds, BPEC.

Designers and installers of solar thermal hot water systems must have appropriate qualifications and have undergone suitable training.

K	Degrees Kelvin (temperature scale)
C	Degrees Celsius (temperature scale)
m	metres
a	annum (year)
W	Watts
kWh	kilo Watt hours
J	Joules
gtoe	giga-tonnes of oil equivalent

The Sun as a Source of Energy

Primary energy sources can be classified as renewable and non-renewable sources. These primary sources are transformed into the intermediate sources, chiefly electricity and fuels. The global yield of the transformation of energy is very low, in the order of 2.5%. This means that 97.5% of primary energy is not utilised by man but is merely withdrawn from nature.

World annual energy consumption is equal to 9gtoe (giga-tonnes of oil equivalent). We have available to us, from coal, 800gtoe and from solar radiation 25,000gtoe. So, it makes very good sense to use the available solar energy, and save precious non-renewable resources (*see Figure 1*).

The sun is an inexhaustible source of energy (by human standards). It can be likened to an integral radiator (black body) at a temperature of 5777K (1 degree Kelvin = I degree Celsius, 0°C = 273K) which sends us 1367 W/m2 of energy.

The relative movement of the earth with respect to the sun, and to itself, explains the positions the sun takes for a given observer on earth. To properly position a solar installation, it is necessary to know the terminology of the most important angles for the position of the sun and the collectors. The sun is always moving in relation to the collector, both by azimuth and altitude. In general, the optimum position for irradiation is facing due south and pitched up at the same angle as the local latitude. However, where the sun's energy is dispersed through clouds, the angle of pitch can be reduced without significant loss.

The solar radiation crosses the atmosphere and on its path undergoes changes in intensity and direction as a result of its interaction with atmospheric components. The main interaction is of two types: absorption and diffusion.

Absorption

Fair-sized (in relation to the wavelength of solar radiation) atmospheric components can totally absorb the radiation beamed at them, thereby reducing the radiation intensity. On the other hand, the internal energy, and as a result the temperature of the atmospheric components, increases and they are converted into long wavelength radiation emitters which impact, in part on the earth, contributing to the resulting diffuse radiation.

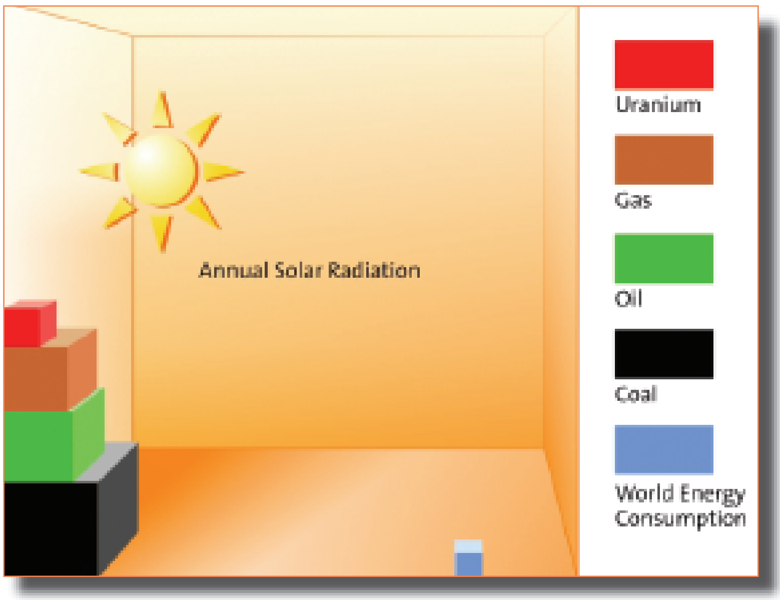

Figure 1: World primary energy reserves

Diffusion

Components of smaller size (e.g. air molecules) produce variations in the direction of the radiation beam, thereby causing dispersion and giving rise to diffuse radiation of a short wavelength which reaches us from any point of the celestial sphere (*see Figure.2*).

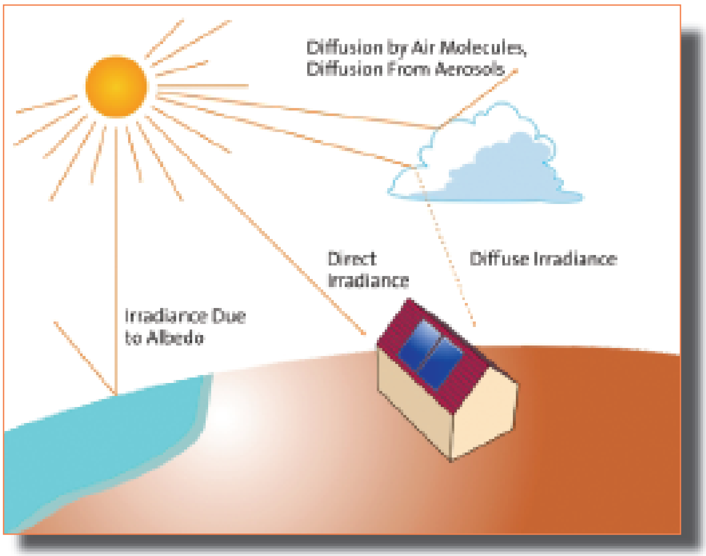

Figure 2: Interaction between solar radiation and the earth's atmosphere

From what we have seen, it is clear that solar radiation which reaches a collector has the following components:

- the direct (beam) component which comes from the solar 'disc' without change in direction
- the diffuse component which comes from the entire celestial sphere
- the reflected component which comes from the ground as a result of the reflection of direct and diffuse components by the ground.

(Note: Solar thermal installations without 'concentration' make use of the direct, diffuse and reflected components of solar radiation. Models with 'concentration' make use only of the direct component).

On clear days there are very high levels of irradiance which can be in the order of 800 to 1000W/m^2, while on completely overcast days only 200W/m^2 or less are obtained. Seasons can also have an effect on irradiance levels. Solar irradiance is the power of solar radiation per unit surface area, expressed in W/m^2. Solar irradiation is the energy of solar radiation over a given period of time, expressed in J/m^2 or in kWh/m^2. On a good summer day, UK irradiation levels can go up to 6kWh/m^2 (*see Figure 3*).

The available solar energy differs from one geographic area to another and there are also variations throughout the year. In desert areas close to the equator, annual irradiation levels of up to 2200kWh/m^2/a are recorded. This is almost double the annual average obtained per sq.m in Central Europe. In the UK the values vary from 850 to 1200kWh/m^2/a.

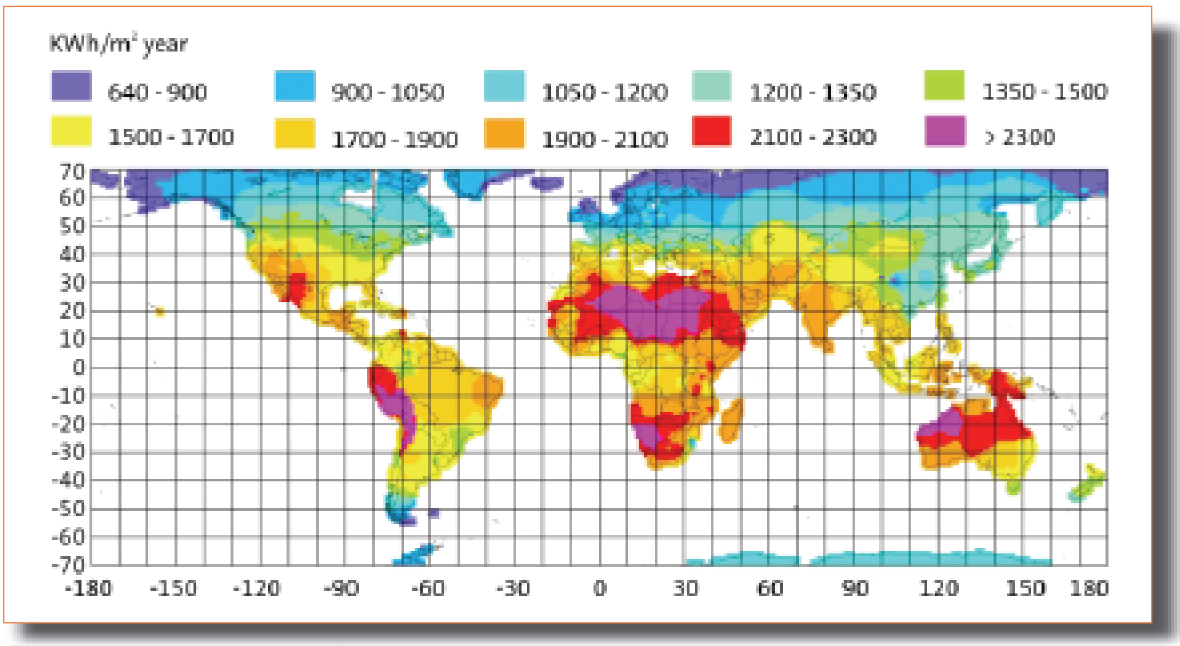

Figure 3: World annual average radiation

Solar Collectors

A solar heating collector is a device that transforms solar radiation into internal energy in a fluid, which is normally water or air. Above all, it should have a long useful life of several decades. The general characteristics of a solar heating collector are as follows:

- resistance to environmental conditions
- resistance to high and low temperatures
- stable and durable
- easy to install
- efficient energy conversion.

Standards:

- EN 12975 Thermal solar systems and components. Solar collectors. Part 1. General requirements and Part 2. Test methods

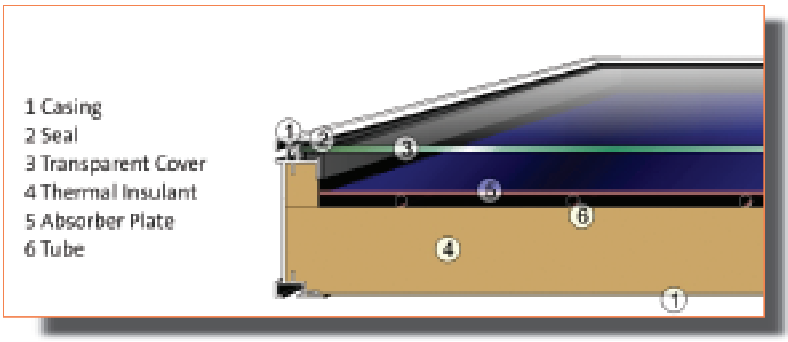

Figure 4: Flat plate collector construction

Flat-Plate Solar Thermal Collector

These collectors consist of a casing, a transparent cover, thermal insulation material, an absorber plate and tubes. The transparent cover produces the greenhouse effect above the absorber plate, allowing the majority of the incident solar radiation through. The absorber plate produces the energy conversion from solar radiation to internal energy in a fluid. It is normally made from metal and painted or covered with a black material that has a high solar energy absorption rate. The tubes contain the fluid that carries the energy out of the collector (*see Figure 4*).

Vacuum Tube Collectors

Advantages of Vacuum Tubes:

- higher operating temperatures can be achieved than with flat-plate collectors. The higher temperatures can be of benefit for process heat (e.g. for industry and solar cooling)
- less thermal losses than with flat-plate collectors due to excellent heat insulation
- higher energy yield than flat-plate collectors with the same effective absorber area. This can be of advantage with installations in small set-up areas. However, the higher energy yield of vacuum tubes is only realised at high working temperatures
- close compact construction of the collector which requires no interior insulation material, and thus no penetration of moisture or dirt into the collector, and no deposits due to dispersal of interior insulation (*see Figure 5*).

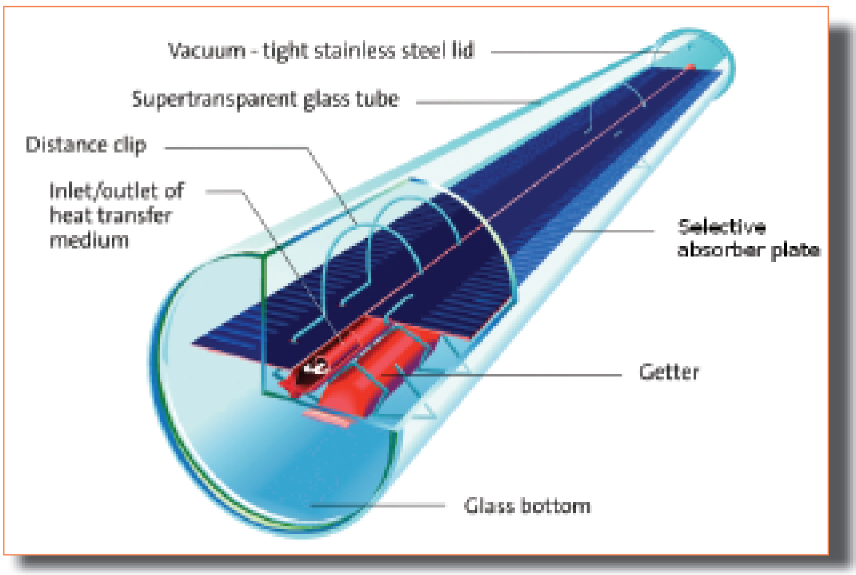

Figure 5: Vacuum tube collector construction

Disadvantages of Vacuum Tubes:

- high stagnation temperatures with corresponding demands on all materials used near the array and on the heat transfer fluid
- considerably higher specific costs than flat-plate collectors. The high cost is compensated for if only low to medium working temperatures are required (e.g. with solar potable water heating), despite higher efficiency and reduced array area
- higher costs for available solar heat at medium operating temperature range, since cost advantages are only at higher operating temperatures.

Principle of Solar Thermal Collection

The schematic explains the main energy interchanges in a solar heating collector (*see Figure 6*).

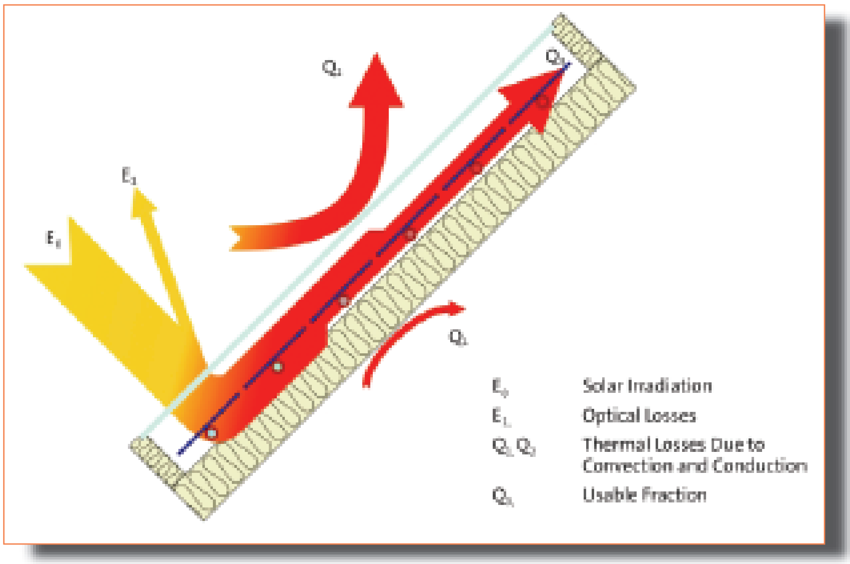

Figure 6: Principle of solar thermal collection

Optical Losses:

From 4-6% of the incident radiation can be lost by reflection, depending on the type of glass. If the transparent cover is not glass, the reflection rate may be very different.

Thermal Losses:

The main thermal losses in a solar collector are produced by the front face (transparent cover), which are approximately 80% of the total losses. The rest of the losses are through the rear face and the sides. These losses depend on the thermal insulation used and the temperature and wind speed conditions in the environment.

Efficiency of a Solar Thermal Collector

The efficiency of a solar heating collector (absorbed energy/incident solar energy) depends on the difference in temperature between the absorber plate and the environment at each radiation level. For any given temperature difference, the efficiency is higher when solar radiation increases.

Flat-plate Collector Area

The performance of a solar collector is normally specified with a given 'reference area'. European standards for collector testing (EN 12975-2) make reference to the opening (aperture) area (the area through which the incident radiation crosses) as well as the absorber area. Given this, it is important to clearly define the collector area referred to in each case. For example, when giving global loss information for a collector (W/m^{2}K), the information may be very different depending on whether the opening area or the absorber area is used.

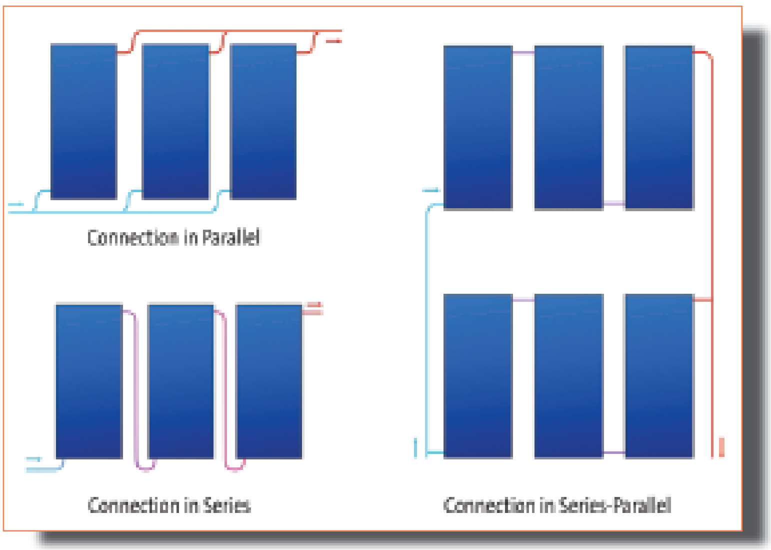

Figure 7: Collector configurations

Collector Layout

With a 'series' connection higher temperatures are reached (lower energy efficiency) and there are higher pressure losses. Lower pressure losses and lower temperature differential (higher energy efficiency) can be achieved with a 'parallel' configuration. The 'series-parallel' combination is a mixture of the two previously mentioned connections (*see Figure 7*).

Solar Thermal Systems

Solar Installation – Pumped Circulation

The figure shows a typical solar heating installation providing hot water in a house. It is an indirect, closed loop, pumped system. The fluid that flows through the collectors is isolated from the potable water supply, which permits the use of antifreeze. The pipework and components between the storage and collector could be arranged in one of two ways:

i) To permit all the air to be fully removed by an antifreeze solution which normally remains in the collector.

ii) To permit some air to be retained, acting to only fill the collector with fluid when the pump is operational (*see Figure 8*).

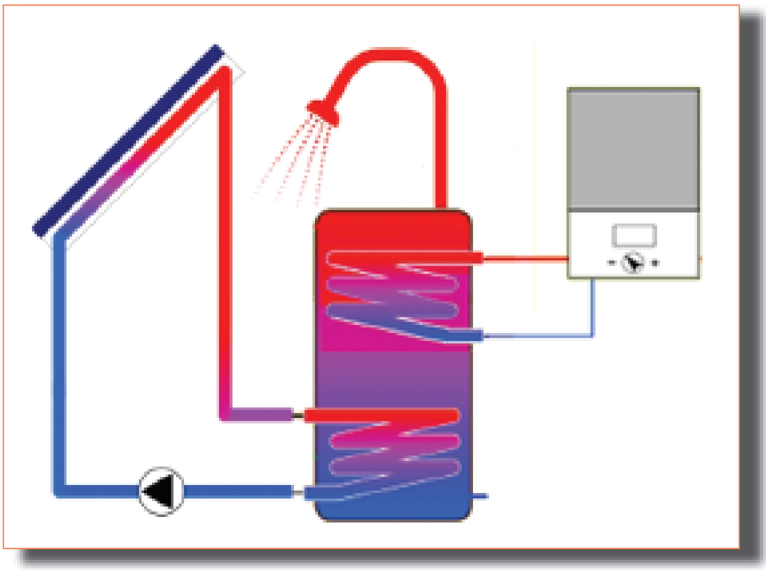

Figure 8: Pumped circulation

Storage Vessels

A solar heating installation requires an energy store that effectively de-links the supply (the sun) from the demand (hot water when required by the user). A storage tank is an element of the solar heating installation that permits thermal energy storage with the lowest possible energy losses.

The most common are thermally insulated tanks that may include a heat exchanger. The most important aspects of a tank are its mechanical resistance, its durability and the quality of the insulation. The lower the heat loss coefficient the better the performance of the tank. The format of the tank, i.e. height to width, greatly influences the stratification.

A properly designed solar storage tank should allow 'stratification' to occur, which is the vertical distribution of water based on temperature, which will improve the system operation. The main advantage of temperature stratification is that system efficiency is increased, due to the fact that the hottest water is at the highest part of the tank. It is this hot water that is used, while the return water is directed towards the collector. This cold return-water increases the collector efficiency.

Thermal losses in a solar heating system occur mainly at night, in the tank, and good insulation is therefore required. The main areas where thermal losses occur are the piping connections and non-insulated metal covers. The importance of tank thermal insulation is demonstrated by the following:

A 300l tank (typical large domestic installation) that is not properly insulated can lose approximately 1200kWh per year, equivalent to at least 2m^2 of collector contribution.

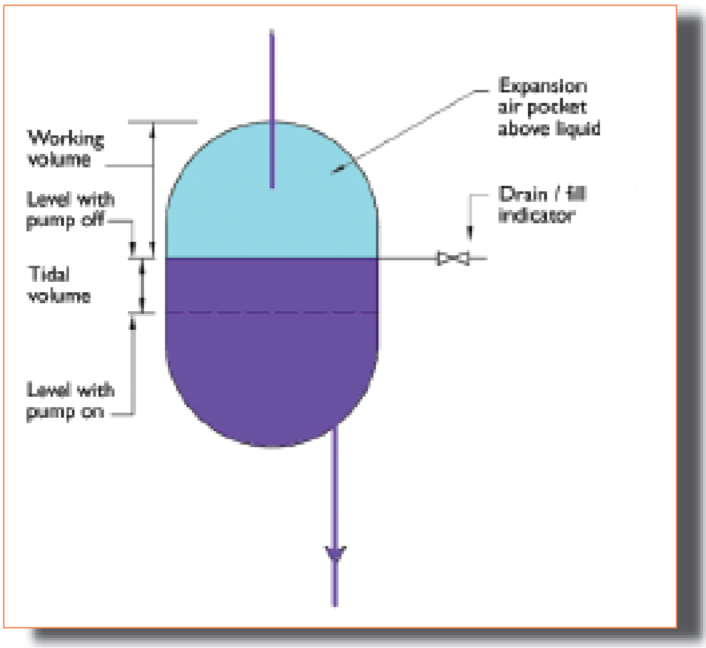

Figure 9: Drainback vessel

Expansion Vessels

A vital component used in fully-filled sealed systems, the expansion vessel absorbs variations in pressure and volume in a closed loop circuit caused by changes in temperature in the circulating fluid. Generously over-dimensioning the expansion vessel is recommended. Expansion vessels up to 35l may be connected directly to the corresponding piping, preferably connecting the inlet to the upper part of the vessel. When larger expansion vessels are used, they are normally floor-standing units connected to the piping in the lower part of the vessel.

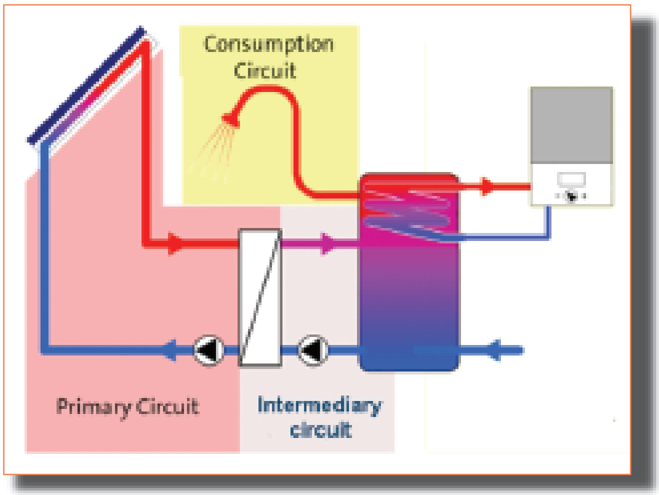

Figure 10: Primary circuit with an external heat exchanger

The expansion vessel is a tank divided into two parts by an elastic membrane. On one side of the membrane is the operating fluid (normally antifreeze/water in a liquid state) and on the other side is air, or an inert gas, pressurised to the working pressure. The initial pressure is established at the factory and may be adjusted later during installation.

The main function of the expansion vessel is to absorb the variation in the operating fluid volume due to changes in its temperature and phase. The minimal expansion volume will be the total volume of the solar collectors and will vary based on the use of the installation. It is important to take into account the vapour generation (due to stagnation) when sizing the expansion vessel.

The design should not use the expansion vessel outside of the pressure limits recommended by the manufacturer, hence a safety pressure relief valve is essential. Do not forget that the operating fluid in an exterior installation may be subject to temperatures from sub-zero to over 150°C, hence the vessel working volume must accommodate a wide range of fluid expansions.

Drainback Vessel

A vital component used in partly-filled drainback systems, the drainback vessel is a single tank. The height of a drain/fill point sets the ratio of air to liquid within the vessel when it is filled. The air is also present in the pipes and collector above this level. The system is not pressurised above atmospheric intentionally and the liquid may be plain water or an antifreeze/water mixture (*see Figure 9).*

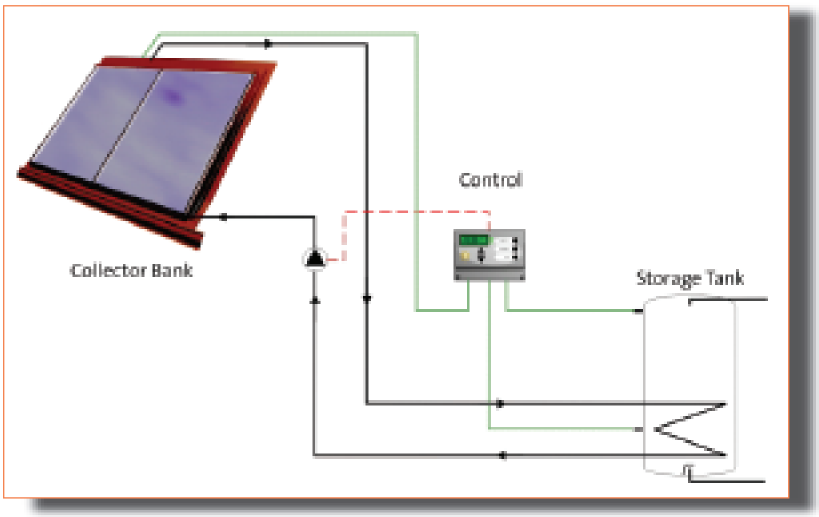

Figure 11: Control on a pumped system

The main function of the vessel is to permit the exchange of air and liquid within the drainback system, but it can also absorb the variation in volume of the operating air/liquid ratio due to changes in temperature. It is NOT necessary to take into account vapour generation when sizing the expansion vessel since the pump is expected to switch off before such high temperatures are reached. The design should not use the vessel outside the pressure limits recommended by the manufacturer, hence a safety pressure relief valve is essential in a sealed system.

Circulation Pumps

Pumps are used in solar heating installations to circulate the operating fluid. The pumps may be inline, dry, wet or surface mounted, and are usually located on the return side of the circuit.

Valves

Solar heating installations require the use of different types of valves: shut-off valve, check valve, pressure relief valve, regulator valve, fill valve, thermostatic valve.

Primary Circuit with External Exchanger

The primary circuit is the heat generation circuit, made up by the collectors, the pipework and connections. This is where the operating fluid captures the thermal energy that is produced and transmits it directly, or through a heat exchanger, to the solar tank (*see Figure 10*).

The intermediary circuit is the circuit in which the operating fluid captures the energy transferred from the primary circuit to be stored.

The consumption circuit is the secondary circuit in which water is drawn off for use.

Back-up Heating

As a result of the difference in time between the energy input and use, and the limitation in the tank size in a solar heating system, it is convenient to include a back-up energy source. This makes energy available for consumption at any time that the user requires it. There must be separation between the two heat sources to permit the solar energy to work on the coolest part of the circuit.

Control – Pumped Circulation

The control of the circulation of solar heat is vital for safety and economy. When the installation uses forced circulation, it is also necessary to use a control system based on the operating fluid temperature at the collector outlet and at the bottom of the tank. Overheating the domestic hot water can be achieved by switching off the pump when the tank is hot enough.

Special attention should be given to proper sensor installation and precise temperature measurement for the two sensors. A control device should be used that includes a display which shows the values most significant to the system operation. In any case, it is interesting to know the temperature of the fluid available for consumption (*see Figure 11*).

Control devices exist that report system operation errors. It is especially important to have the technical documentation for the control system available for future reference.

It is important that the temperature sensors are properly located and operate correctly, in particular the sensor monitoring the control temperature of the storage tank. For example, if the level is set too high, pump operation will be inadequate.

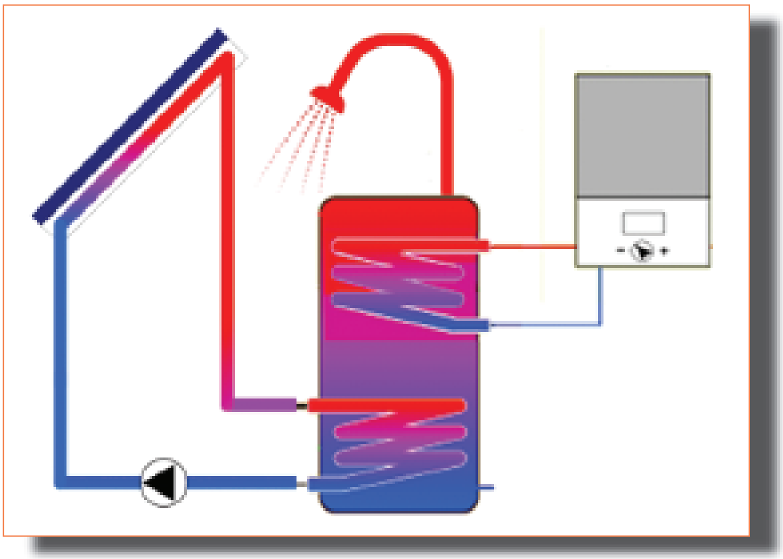

Figure 12: Indirect, pumped circulation, with heat exchanger incorporated into a solar tank

Control Operating Principle

In a system with pumped circulation, the pump starts when the temperature difference (between the lower part of the tank and hottest part of the collector) is higher than a specified value (approximately 7 or 8°C). The pump stops when the temperature difference is lower than a specified minimum limit (approximately 2 to 4°C).

Indirect, Pumped Circulation, with Heat Exchanger Incorporated into a Solar Tank

This configuration is frequently found in small- and medium-sized installations. It combines the solar and back-up heating elements into one vessel (twin-coil). The heat from the solar system naturally rises to the top of the storage tank ready for top-up from a boiler or electrical immersion heater. If the solar heat is hot enough, the thermostats will respond to reduce heating from the back-up system (*see Figure 12*).

This configuration has a major advantage: it blends in effortlessly with the architecture since the tank can be located in many locations e.g. in the basement of the building. Moreover, it allows control of overheating the domestic hot water, permits the use of antifreeze and anti-corrosion chemicals and reduces limescale problems in the collector circuit. Note that if hot water is consumed predominantly in the evenings or at night, the back-up system detects a reduction of temperature in the storage tank that triggers re-heating (unless a timer is fitted). If there is insufficient storage dedicated for solar, the storage tank will already be warm and a very low solar efficiency will result.

Condition	Tensile strength (minimum)	Elongation (minimum)
Annealed (R220)	220N/mm^2	40%
Half-hard (R250)	250N/mm^2	20%
Hard (R290)	290N/mm^2	3%

Mechanical properties of copper

Pipework

It is evident that a solar heating installation requires pipework for the operating fluid to circulate. Correct sizing and the choice of materials and insulation are key aspects in achieving a good solar installation.

Copper Tube and Fittings

Copper is an ideal pipework material for the primary circuit as it is perfectly capable of withstanding the high temperatures that the operating fluid reaches. The joints and connections with other system components should also be able to withstand the working temperatures and pressures. Thought should be given to preventing corrosion due to dissimilar metals in contact (*see Figure 13*).

Copper has a number of advantages when used in solar thermal installations, including:

- durability
- maintains mechanical properties over a wide temperature range
- easy to install
- easy to recycle
- resists passage through abrasive sharp edges
- lightweight
- readily available
- allows installations to be easily modified.

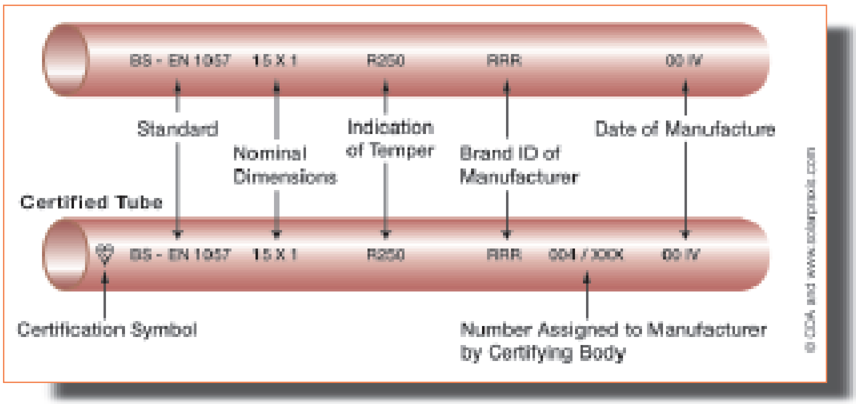

Figure 13: Copper tube

Jointing

Copper pipework can be jointed in a number of ways; compression fittings with olive and brass support sleeves, brazing (Copper-phosphorus filler metal), press fittings with high-temperature o-ring, flat faced union with washer and paste. The high temperatures that can occur in solar thermal installations preclude the use of some jointing techniques.

Capillary soldered joints can only be used where the operating temperature is less than 110ºC. Soft solder alloys are specified in BS EN 29453. The melting point of soft solder filler metals is less than 350ºC. Solders most commonly used are of the tin-copper and tin-silver type.

Brazed joints will perform at higher temperatures and pressures than soldered joints. Filler metals for brazing are specified in BS EN 1044. Melting point of filler metals is less than 800ºC. The copper-phosphorus (Cu 94%, P 6%) brazing alloy is used commonly.

Pipe fixings should be metallic where in contact with metallic pipes in the solar circuits. For reduced heat-loss, pipe fixings that clamp over the pipe insulation can be used.

Thermal insulation is a fundamental part of any solar heating installation, in particular, in tanks and pipework. The following circumstances should be taken into account when choosing insulation materials to be used in a solar installation:

- it should be able to withstand elevated temperatures (125ºC for long periods of time, and up to 180ºC for short periods of time).
- it should be resistant to the effects of an outside environment (ultraviolet radiation, corrosion by external agents) and nature (small animals and birds).
- it should fulfill the requirements of the current standards for thickness and conductivity.
- the insulation should cover all piping and system components, leaving uncovered only those elements required for the proper operation of the system.

System Design

Planning

At the planning stage some idea of the type and size of the installation should be known, together with the likely energy demand from the system. It is important that the roof structure is strong enough to support the weight of the proposed solar installation.

Installation Checklist

- Collection of data (hot water consumption, meteorological data etc.).
- Drafting a site plan.
- Knowledge of regulations and standards.
- Design and dimensioning, area of collectors, volume and location of the storage tank, length of pipework, pumps, expansion vessel, heat exchanger, insulation, pressure losses, structures.
- Final design and implementation of project.

Domestic Hot Water Consumption

This factor (together with solar radiation) has the greatest influence on the efficiency of an installation and yet, many times it is the least known. There are large differences in consumption, both of families and of hotels, hospitals, industries, for which reason it is recommended that measurements are made whenever possible. If no measurements are available, graphs, developed from a study based in Germany, can be used.

For sizing the solar system it is reasonable not to suppose 100% solar availability throughout the entire year. What must be taken into account is that buildings are not always used at full capacity. It is recommended that the dimensioning of large-scale solar thermal installations be made on the basis of measurements taken during the summer when consumption falls off considerably. There is a great range in consumption values as well as in the concept of 'personal' or 'unit design'.

The sizing values must be checked with regard to the temperature on which these values are based and for the allowance made for average occupancy of the buildings. In general, it can be assumed that dimensioning values are too high. Note that there will be different values if we assume the water is used at 45°C compared to 60°C.

Meteorological Data

To size a solar installation, it is necessary to have the overall solar radiation data in order to locate the solar collectors, as well as data on the 'local' ambient temperature.

The most common method is to use the representative daily values (average or measured) for each month. Depending on the calculation method used, it may be necessary to use fewer aggregate values (daily, including hourly values).

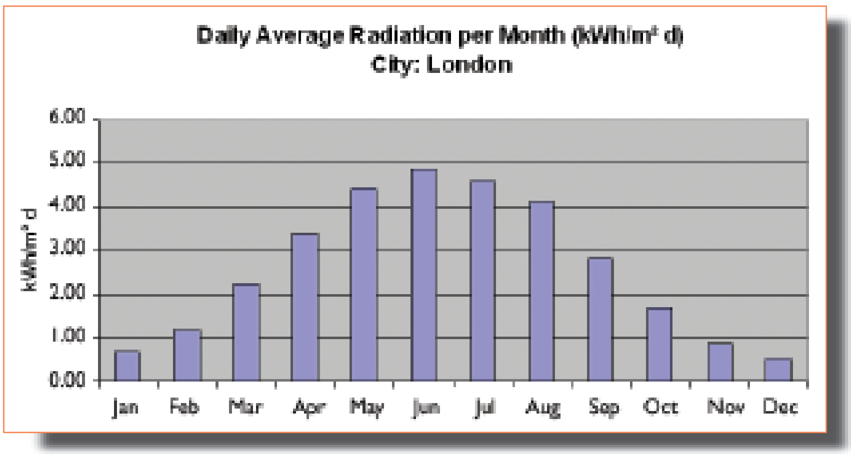

Figure 14: Daily average radiation values per month for London

The radiation data are usually available in tables and/or databases. These come from measurements by specialised centres (computerised simulators, such as TSOL, and universities) and have undergone subsequent processing to supply radiation values for inclined surfaces which are needed for the sizing of solar installations (*see Figure 14*).

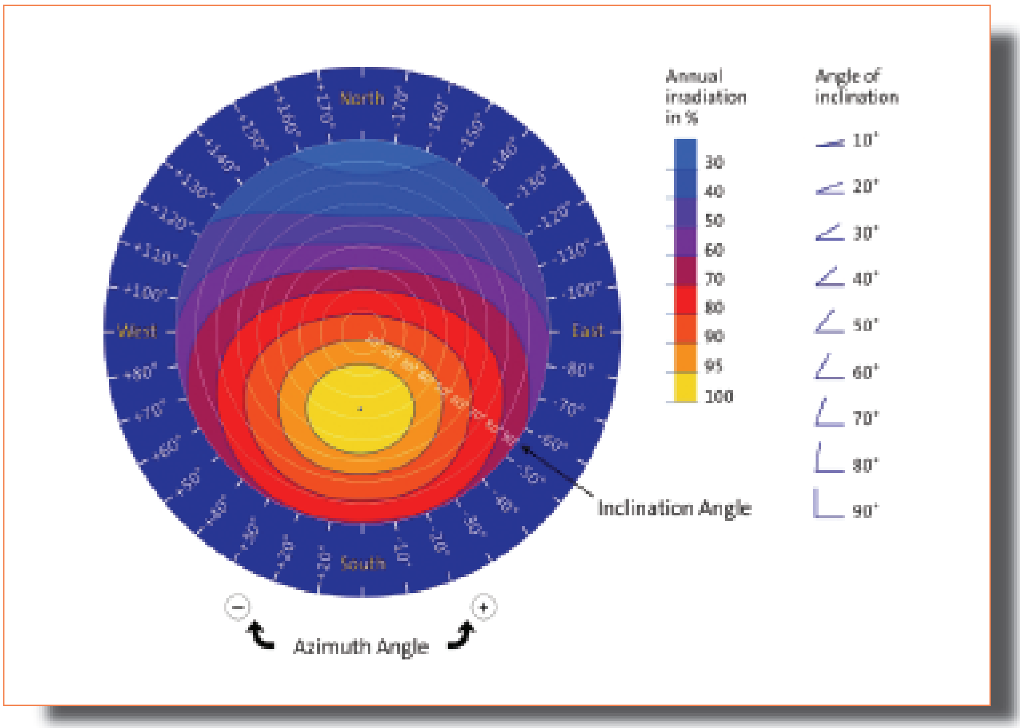

Figure 15: Collector orientation

Ambient temperatures are also supplied by these institutions but can also be found in handbooks for professional installers. Figure 14 shows global radiation values calculated for a horizontal surface with an inclination equal to 0, as is the case in London.

Collector Orientation and Inclination

Graphs like the one in Figure 15 show the criteria for locating the solar collectors on the available surface. In general, it is better to install the collectors on the roof of a building. If the orientation and inclination of the roof are not optimal, variations in orientation and inclination as shown in handbooks and the standards may be accepted. In applications with seasonally different consumption, it is advisable to use inclinations matching these circumstances. For example, in a hotel for summer residence, the collectors must be less inclined than in one for winter residence (*see Figure 15*).

Site Inspection

It is necessary to make a detailed inspection of the site and to draft a sketch showing the layout of the installation and/or its components. One should not forget to take a compass along to determine the correct position of the collectors. In this case, it is useful to take the south at several locations as there may be situations (e.g. with iron tubing) which affect the magnetic field. In addition, a hand drawn sketch of the site should be made.

Sizing of Installations

To simplify matters, the following process can be employed:

The hot water demand for a reference day of every month of the year is determined and put into the form of a diagram as shown in the Figure. In this case, it is assumed that the demand is uniform throughout the year (*see Figure 16*).

For a given quantity, the solar storage volume must be sized in such a way that 1.0 to 1.5 times the daily demand is available. Assuming a given V/A ratio (e.g. 50 - 75l/m²) provides a first approximation of the collector surface.

The same diagram shows the respective solar radiation for each month, (MJ/m². per day or kWh/m². per day) for the inclined surface on which the collectors will be installed (e.g. 45°). With these radiation and collector size values, it is then possible to calculate the energy supplied by the collector banks. Taking established criteria (maximum of 3 months of 90% of solar availability and a minimum of 50% throughout the year etc.), it must then be checked whether the requirements are met. If this is not the case, the necessary adjustments must be made.

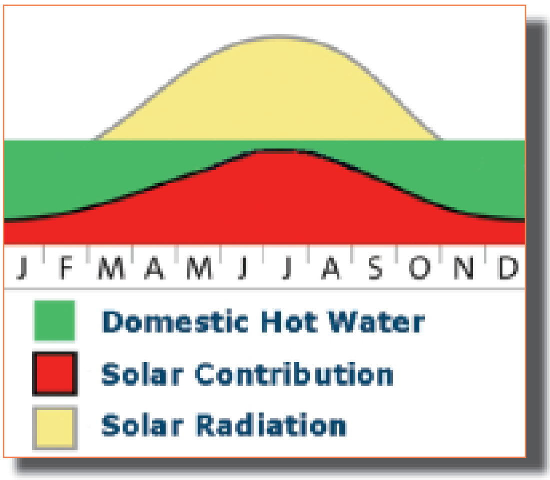

Figure 16: Determining hot water demand

For the sizing of installations, any of the commercially available calculation methods can be used. The F Chart method, much used by many planners, may not be sufficient to calculate large installations. For these, the use of calculation programs employing simulation methods are recommended. The calculation program will specify, at least on a monthly basis, the representative daily values for solar energy demand and supply. These will also include the annual overall supply defined by the:

- demand for thermal energy
- solar thermal energy provided
- solar fraction
- average annual yield.

When sizing the solar thermal installation, it is reasonable not to assume 100% of solar availability throughout the entire year. It should be borne in mind that buildings are not always fully occupied (100%).

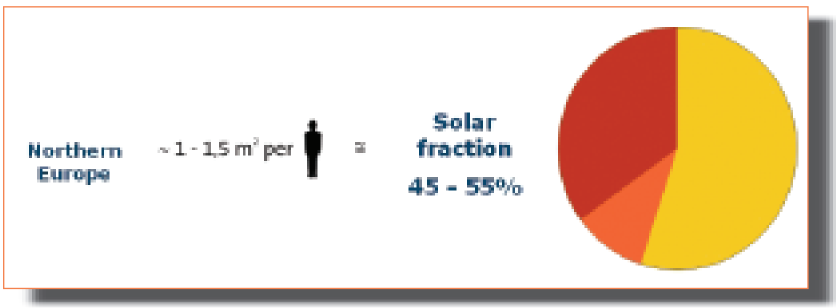

Figure 17: Sizing of collectors

Sizing of Collectors

These are empirical values for an installation facing due south and are valid only for up to about 5 users (*see Figure 17*).

In any case, it is convenient to revise the initial design using a calculation program.

Sizing of Storage Tank

The Figure shows the case of a small-sized household installation. Assuming 6 people with a daily consumption of 50 litres per person at 60°C, i.e. a daily consumption of 300 litres equals the volume of the solar storage tank.

Assuming a volume/collector area ratio (V/A) = 50 - 75 l/m², results in a collector area of 4 - 6m² (*see Figure 18*).

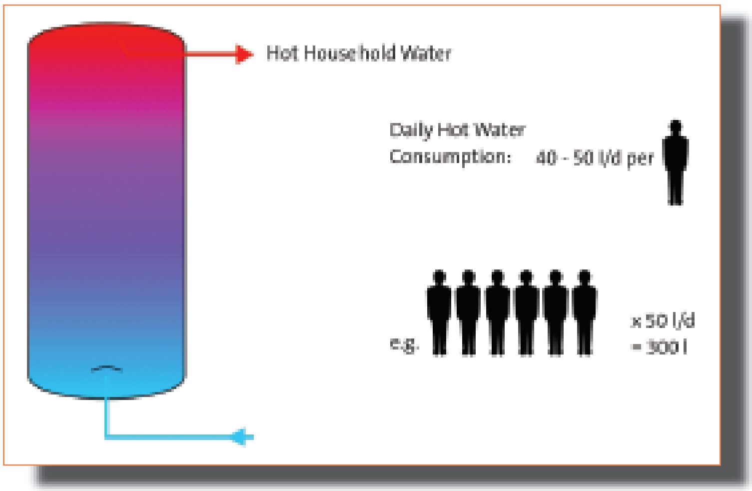

Figure 18: Sizing of storage tanks

Pressure Loss in Flat-plate Collectors

The pressure losses for different flat-plate collectors (A,B,C,D,E) can be found from the graph. Using the flow rate in the collector banks calculated from a specific flow rate (50l/m²/h or the minimum flow rate specified by the manufacturer), the graph gives the pressure loss in mbar. To convert the value to mm of water equivalent, it is sufficient to multiply by (approximately) 10.2 (*see Figure 19*).

With connection in series, the pressure loss is determined in the following manner:

Pressure loss of a collector for the total flow rate (as per graph or documentation of the manufacturer) multiplied by the number of collectors connected in series.

Pressure Loss in Pipework

Once the flow rated is obtained, it is entered into the table to obtain the pressure loss for the different diameters and values of the linear velocity of the fluid.

It is important to consider which fluid is being used as glycol is more viscous than water and hence will have greater pressure losses than water. This can be accounted for in the design of the system by multiplying by 1.3 (a good approximation). (*See Figure.20*).

The diagram is valid for copper tubes and an antifreeze mix of 60% water/35% glycol at 50°C.

It is recommended that the tube diameters are sized in such a way that the pressure loss per linear metre is at most 4mbar/m (40.8mm of water column per metre).

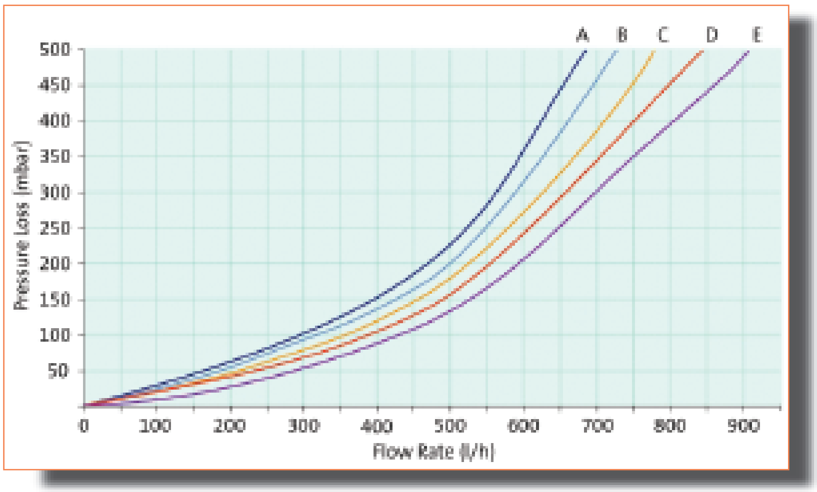

Figure 19: Pressure losses in flat plate collectors

Care must also be taken to ensure that the velocities inside the tubes do not exceed a certain level, to prevent acoustic effects (approx. 1.5m/s); a velocity of between 0.4 - 0.6m/s is recommended.

For small systems, the manufacturer's documentation should be consulted. In medium- and large-sized systems, calculation programs are used. If no calculation program is available for pipework, it is possible to calculate the pressure loss for the pipe lengths and then the pressure losses for elbows, adapters, valves, can be equated to 10% of the pipework losses.

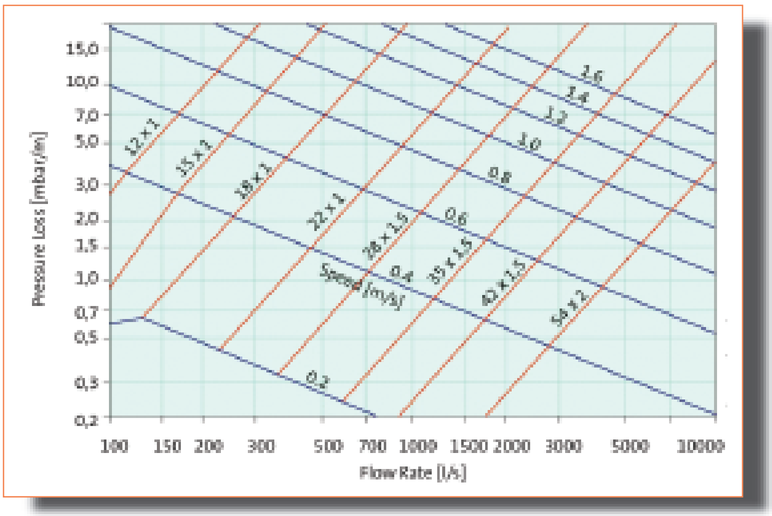

Figure 20: Pressure losses in pipework

Pressure Loss in Heat Exchangers

Twin-walled heat exchangers have a pressure loss that is so small that it can be ignored. Internal heat exchangers (coiled type) have a relatively low pressure loss (equal to that of the tubing) as can be seen in *Figure 21*.

External plate heat exchangers have relatively high pressure losses (see values of manufacturer). It is recommended that they are sized in such a way that the pressure loss is less than 300mbar/m (3060mm of water per metre).

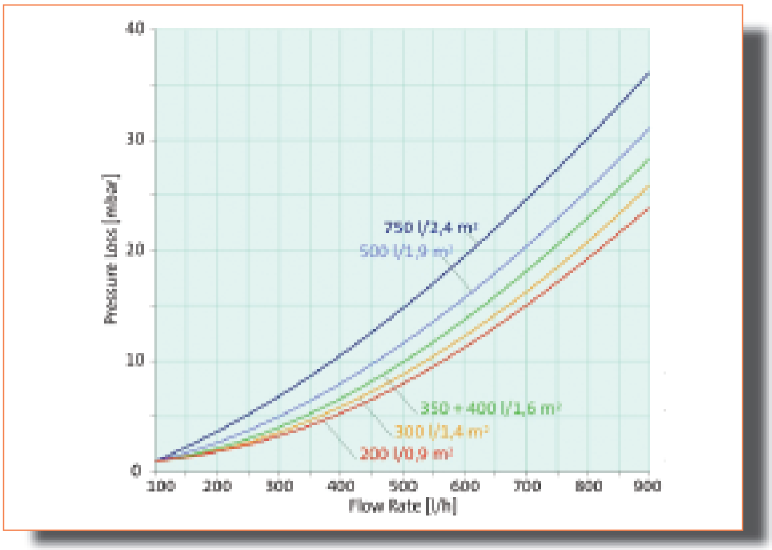

Figure 21: Pressure losses in heat exchangers

Pressure Loss due to Accessories and other Components

The pressure loss in certain components of solar installations can be substantial, for example:

- flow gauge: in the order of 20mbar
- return check valve: in the order of 10mbar
- energy counter: in the order of 50mbar
- filters: these can cause high pressure losses due to the build-up of debris
- compensating valves: on a case-by-case basis.

In order to approximate the pressure drop from incidental components, such as straight valves, elbows, add an additional 10% on to the figure calculated for the pipework.

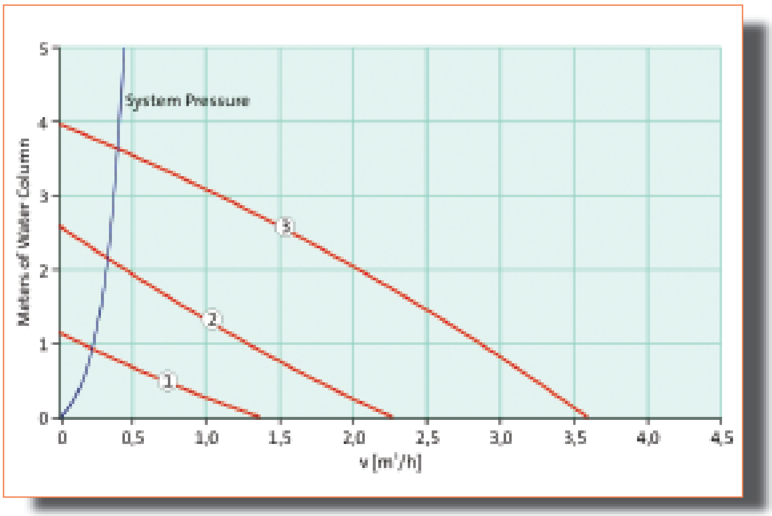

Figure 22: Sizing of pumps

Sizing of Pumps

The pressure which the pumps must supply is calculated on the basis of the collector area. In addition, the pumps must compensate the pressure losses in the circuit. These two data are entered into the graph and the operating point of the required pump is obtained (*see Figure.22*).

The pump that is readily available on the market and closest to the calculated value should be selected. Pumps are mainly supplied by the heating and air-conditioning sectors and as a rule are not optimally adapted to the needs of small solar installations. It must be borne in mind that the power consumption of the pumps may not be negligible.

Sizing of Heat Exchangers

Coiled Type:

Approximately $0.2m^2$ surface exchanges per m^2 of collector (coiled type) or $0.35m^2/m^2$ of collector (blade type) respectively.

In any case, the ratio between the areas must not be less than 0.15.

Plate Type:

The minimum designed power (in W) is given by
$P \geqslant 500 \times A$
(A = area of collector in m^2.)

It is recommended to oversize the power and reduce the pressure loss (which must not exceed 300mbar/m (3060mm of water column per metre)).

Sizing of Expansion Vessels

These must not be sized in the same way as those for a heating system as there are certain differences between solar energy and simple heating installations. They have a higher temperature range and the anti-freeze fluid has a higher coefficient of expansion.

The expansion vessel must be sized in such a way that the pressure of cold fluid, at the lowest point of the circuit, is not less than 1.5bar and the pressure of hot fluid, at any point in the circuit, is not greater than the maximum operating pressure of any of the components. The safety valve must be calibrated at a value below the maximum operating pressure of the component that can withstand the least pressure.

The maximum pressure (PM) must be somewhere in the region of 10% below the calibrated pressure of the safety valve. The expansion tank must compensate the following effects:

- Ve - expansion volume (thermal expansion of the fluid)
- Vvap - volume due to vapour generation that may be created in the collectors and in the tubing during system stagnation.

Adjust the initial pressure of the gas(Pi) in the expansion vessel to be equal to the pressure when cold at the highest point plus the static pressure (altitude adjustment 1bar = 10m).

In areas prone to excessively low temperatures it is appropriate to adjust the initial gas pressure in the vessel to a somewhat lower level. When doing so, the vessel will supply the fluid to the remainder of the installation when the fluid contracts (spare volume Vr).

General Considerations

The main objective of a solar thermal installation is to produce hot water as and when desired. To achieve this goal, the correct assembly of the installation is crucial.

The first objective is to be aware of the need to comply with Building Regulations and Standards. The second important point is to follow the mandatory safety precautions required for the assembly of the installation.

Some of the aspects to be taken into account are dealt with below:

- careful workmanship is indispensable to ensure a long service life
- quality and durability of materials. Materials and construction must be able to stand up to the elements
- possible expansion must be taken into account. Provide protection from freezing
- correct connection to the water mains
- accessibility for maintenance and repair

- correct positioning of all elements, in particular of the sensors, drain and other valves. Proper connection of exchangers
- careful consideration of high temperatures, stagnation, vapour etc.
- do not install an expansion vessel that is too small. It must withstand high temperatures
- do not damage the cover (e.g. do not damage the asphalt fabric).

Summary

House builders and homeowners alike are being encouraged to think about renewable energy sources and solar thermal systems are proving to be an attractive option.

Copper is the first choice for domestic plumbing and heating systems; now its properties can be put to great use in solar thermal installations.

The recyclability of copper, and its well established recycling industry, mean that it is an ideal pipework material for those seeking to help reduce mankind's impact on the planet.

Appendix A – Legionella

Legionella bacteria is found in all mains water in low concentrations, but proliferates at temperatures between 25 to 46°C. Solar domestic hot water can increase the risk of bacterial growth, however, very few cases of Legionnaires Disease have been reported.

The main control measures include storing all solar pre-heated water at greater than 60°C before distribution. Raising to 70°C may be required for instant disinfection i.e. with combi-boilers.

Scalding risks can increase when treating bacteria with temperature. For large domestic hot water stores, raising all storage through 60°C daily is an option. Ensure domestic hot water after-heaters, such as combi-boilers, are powerful enough to reach 70°C in high risk situations.

Heat exchangers can reduce the risk. Pipework design can also reduce the risk of legionella. Reduce excessive branch runs to un-vented expansion vessels. Avoid long domestic hot water pipe runs with standing water i.e. dead legs.

Avoid capped off domestic hot water tees i.e. blind ends. Fit lids to cold water stores, remove sediment, avoid over-sizing them and insulate to keep them cool. Cold water should be kept below 20°C.

Chemical and ultra-violet can also be used to control bacteria growth. Copper and copper alloy metal surfaces have an intrinsic ability to inhibit the growth of algae, fungi/moulds, viruses and bacteria. Studies confirm that these surfaces are effective antimicrobial agents that kill microbes within hours.

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