Expansion vessel in a solar installation

White paper

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Like every closed system in which a liquid's temperature changes, a solar installation also needs an expansion vessel. However, there are some important differences between systems for solar and central heating systems with regard to the location of the expansion vessel and the calculation of the necessary capacity. This is due not only to the medium used but also the way in which solar systems work.

In this white paper, we deal with the following types of solar boiler systems:
- Low-pressure variants (max. 3 bar), such as a solar boiler with return flow.
- An overpressure solar boiler system with an operating pressure between 3 and 10 bar.
- A solar boiler installation with non-glazed collectors.

Solar boilers with return flow

The return flow system broadly corresponds to the overpressure system. The main difference is that there is a return flow vessel in the system into which the medium flows back from the collector as soon as the circulation pump stops running. This protects the collector from both freezing and overheating. The system is very popular for this reason, but has the disadvantage that somewhere has to be found to place the return flow vessel. In addition, a more powerful circulation pump is needed to pull the water back out of the return flow vessel again. For this reason, it is necessary to place the return flow vessel as close as possible to, but below the level of, the collector. All piping must also be placed on a slope to ensure that no water is left behind during return flow and that all air is effectively pushed out of the system when it is being filled.

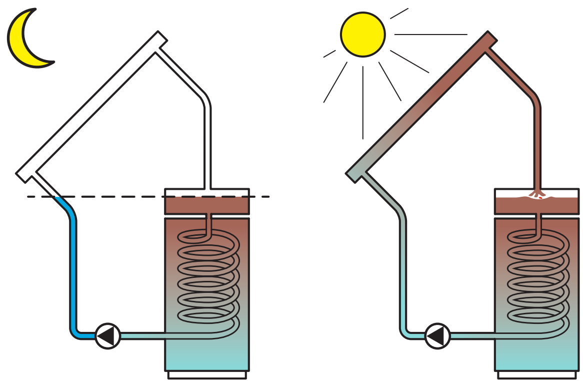

Figure 1.

This system does not require an expansion vessel, or only a very small one, because the system has an air bubble that maintains the changes in volume within the set pressure limits. An advantage of this is that the system can, if necessary, be filled with distilled water, which enables a single-walled heat exchanger to be used for heating the domestic water. This increases the efficiency of the installation.

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Overpressure solar boiler installation

The most frequently used system in Europe is the overpressure solar boiler installation which is filled with a mixture of water and glycol. This mixture is suitable for the high operating temperatures in solar systems that work at a pressure of between 3 and 10 bar.

A solar system consists of a number of components that are important when it comes to selecting the expansion vessel:

- collector
- safety valve
- circulation pump
- heat storage vessel/heat exchanger

All other components are also important, of course, but have less influence on the selection of the expansion vessel.

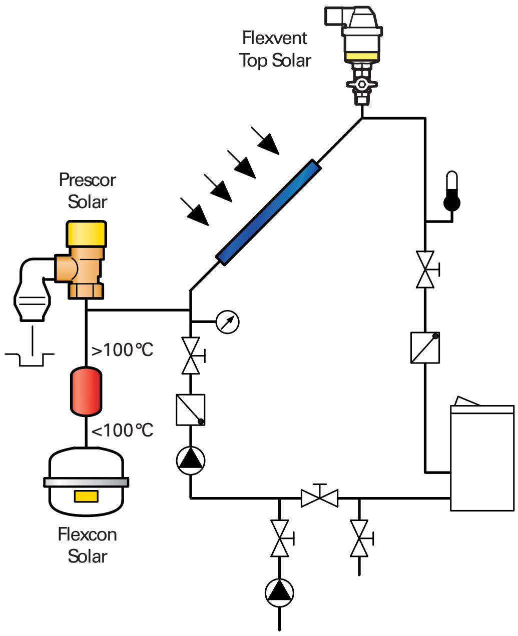

Figure 2.

Expansion vessel ensures pressure maintenance

In this white paper, we assume that the installation is intrinsically safe according to DIN 4757-1. That is to say, it is a fully sealed installation which functions under every logical operating condition. The expansion vessel plays an important role in this regard when it comes to maintaining pressure. The pressure must not rise too high when the circulation in the collector stops, but also not too low when the outside temperature is below the freezing point. The media in solar systems have a high coefficient of expansion; in addition, the temperature can easily fluctuate 150 °C in a year. An expansion vessel must anticipate such temperature fluctuations.

The principle

The discussed solar installation is a closed system that is completely filled with liquid. The heat in the collector is absorbed by the liquid and given off again to the heat exchanger of the boiler. If the heat supply is less than or equal to the heat requirement, the system functions within a temperature range of approx. 80 – 100 °C. The expansion and contraction of the liquid is determined within the operating range by the quantity of solar radiation and the temperature in the boiler.

As soon as the medium in the boiler has reached the desired temperature, circulation stops. The medium present in the collector now warms up until its transitions to vapour form. The medium in a solar installation is mostly a mixture of water and glycol. Although (propylene) glycol is resistant to considerable temperatures, it damages the structure irreparably at temperatures above 150 °C. This can also have an aggressive effect on the installation components. It is therefore important to keep the temperature below 150 °C. This is done by keeping the pressure in the system so low that the medium transitions to the vapour phase well below this temperature. As soon as the collector is filled with vapour, scarcely any heat is transferred and the temperature in the installation no longer increases.

The lower the pressure, the earlier the vapour phase.
A water/glycol mixture in a ratio of 60/40 transitions to the vapour phase at a collector pressure of 5 bar and a temperature of 160 °C. At a collector pressure of approximately 2.5 bar, the medium transitions to the vapour phase at 140 °C.

The influence of the collector on the size of the expansion system

There are various collector designs, including variants in which the liquid is quickly forced out of the collector during the phase transition and others in which this is done extremely slowly. A number of principle diagrams of these types of collector are shown on the right.

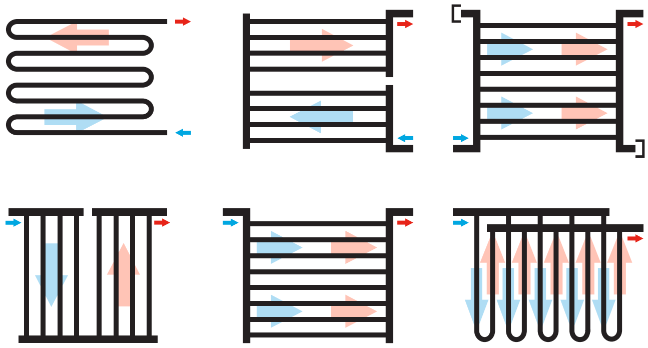

Figure 3.

The top three collectors have the return connection at the bottom and the flow connection at the top. During the phase transition, the liquid is simply forced downwards so that only a small quantity of liquid is transformed into vapour.

In the bottom three collectors, the return flow of liquid is prevented by the vapour bubble created at the top of the collector. This turns a very large amount of liquid into vapour, which has a much greater volume than the liquid. There must therefore be a way of absorbing this volume somewhere in the installation - an expansion vessel. A lot of attention is also paid to this in the calculation page.

The safety valve

The safety valve protects the installation against impermissible pressure. The opening pressure of the valve must therefore not be higher than the permitted pressure of the other components. The expansion vessel ensures that the safety valve always remains closed and that the maximum pressure in the collector is limited. This is to prevent the temperature of the water/glycol mixture rising too high.

Location of the expansion vessel

In conventional central heating systems, the expansion vessel is placed in the return line on the suction side of the pump. The expansion vessel in a solar installation is placed on the pressure side of the circulation pump (see figure 2). This prevents vapour from entering the expansion vessel as much as possible. Vapour in the expansion vessel itself is not wanted because the high temperature of the vapour damages the membrane.

Solar boiler installations with non-glazed collectors

Another variant of the overpressure solar calorifier installations is an installation that makes use of non-glazed collectors. Non-glazed collectors are used in situations where high temperatures are not necessary or wanted, such as the regeneration of ground sources for heat pumps, the heating of swimming pool water, as a heat source for ice buffer systems or as pre-heating for hot domestic or process water.

The advantages and disadvantages
The advantages of non-glazed collectors are that they have better effectivity at lower temperatures, are easier to install, the collector liquid does not overheat and the installation can be added to roof or façade constructions.
A disadvantage is that the effectivity comes under pressure when the installation is exposed to weather elements such as wind and when the system is asked to deliver high temperatures.

The version
There are various versions of the installation. For example, flexible polyethylene tubes, special heat exchangers made from polyethylene, hoses under the roofing on flat roofs, hoses or rigid pipes under aluminium or zinc panels. Finally, it is also possible to opt for full-flow stainless steel panels with a special coating that absorbs the widest possible spectrum of the sunlight and radiates as little heat as possible. The choice of a particular version depends on the desired effectivity. For example, stainless steel panels have a high effectivity and installations that make use of polyethylene a much lower effectivity.

The expansion equipment
The non-glazed collectors, depending on the type and where they are placed, work in a temperature range of ±4 to 50 °C during normal operation.
These installations are calculated as normal central heating installations, taking into account the difference between the filling temperature, the minimum outside temperature and the location of the expansion vessel. It is possible for this expansion vessel to be placed downstream of the pump.

Calculation of the expansion vessel

A spreadsheet is needed to determine the size of the expansion system. This sheet is specifically intended for small and medium-sized solar calorifier installations. These have a collector surface area of approximately 20 to 40 m². In general, this means that the maximum usage of the system is to heat domestic water in an apartment building. In large installations, the control system is also entirely different and it is necessary to relate the size of the expansion system to it

The spreadsheet first asks the user to enter the capacities of the collectors, the lines and the heat exchanger. These are important for determining the various increases in volume. The user is then asked for the static height above the expansion vessel. This is also critical for selecting the correct pre-pressure of the vessel.
Because the expansion vessel is situated on the pressure side of the pump, the sheet asks for the dynamic pressure of the pump. However, if vapour can arise in the system, then the dynamic pressure of the pump is not important. If vapour actually forms, the vapour volume is always greater than the additionally calculated volume produced by the dynamic pressure of the pump. Vapour is only produced in a deactivated pump; it is therefore not necessary to include both in the calculation. In addition, the sheet also asks for the set pressure of the safety valve. This determines the maximum permissible final pressure in the system.
The expansion coefficient of the medium in the installation is automatically set to 10%. This value is determined in consultation with Solarpraxis AG in Berlin. A large number of standard glycol mixtures are available to purchase, all with a different expansion coefficient. Working on the basis of 10%, it can be used for all mixtures.

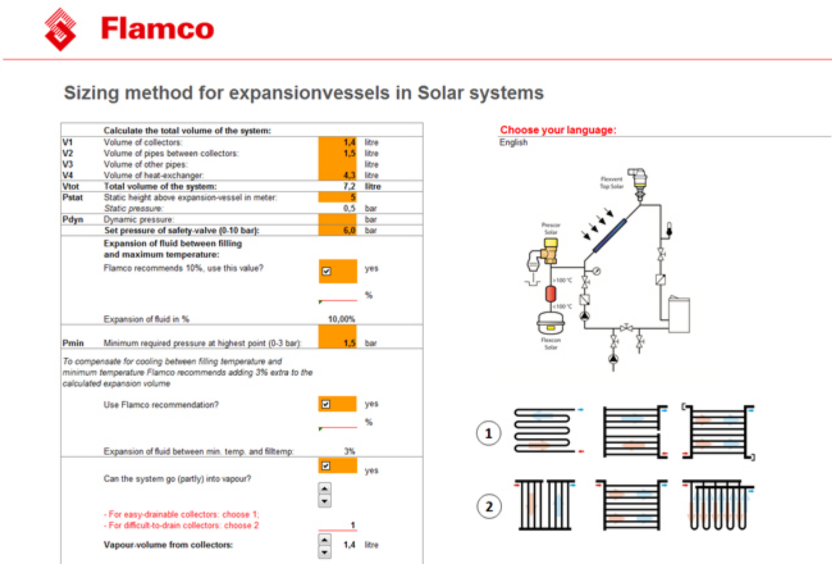

Figure 4.

A setting of 0.5 bar can be chosen for the minimum pressure at the highest point of the installation. A higher minimum pressure results in a lower useful effect and therefore a greater vessel capacity.

Because the installation is filled at ambient temperature and the temperature can fall to -20 °C, the volume of the medium can also reduce. This decrease in volume is estimated to be 3%. The vessel must therefore be large enough to make this volume of water available to the installation again.

Finally, it must be entered whether the system is able to transition to the vapour phase (fully or partially). This point must be carefully checked and filled in. The type of collector plays an important role in this (see figure 3). When using collectors that are difficult to drain, then the sheet asks which sort of installation is being considered (domestic water only, domestic water and central heating, domestic water and central heating in the attic, or other). The values used for the calculation are arrived at in consultation with Solarpraxis AG.

The spreadsheet then supplies the results together with a brief explanation of the values used and a recommendation for the expansion vessel to use. The spreadsheet is intended for small to medium-sized solar boiler systems. The selection table becomes inadequate with increasing capacity and may give incorrect advice. You should therefore always be alert to the plausibility of the results.

	Calculation results				Notes and warnings
Pend	Required pressure safety buffer :		0,6	bar	10% of set pressure of safety-valve with a minimum of 0,5 bar.
	Maximum system pressure :		5,4	bar	
Po	**Pre-charge of vessel :**		0,5	bar	Pstat + Pdyn
Vtot	Total volume to be taken into the vessel:				
	by expansion:		0,7	litre	Vtot x expansion (%)
	vapour-volume:		1,4	litre	
	waterreserve:	3%	0,2	litre	+ Vr
	Total volume in vessel:		**2,3**	**litre**	
Vnom	Nominal volume of expansionvessel:		8,8	litre	

	Vessel selection and filling instructions				Notes and warnings
Vrec	**Recommended Expansion Vessel:**	**Flexcon Solar 12**	**12**	**litre**	
	When filling the system we must take into account:				
	1. Minimum required pressure at highest point:	1,5 bar	6,0	litre	
	2. Compensation for cooling to min. temp:		0,2	litre	+
			6,2	**litre**	
Pf	**Fillpressure Pf:**		**2,1**	**bar**	
	Volume in vessel at Pf:		6,2	litre	
	Pressure at total volume in vessel:		3,9	bar	
	Max. allowable working pressure of chosen vessel:		8,00	bar	

Figure 4.

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If you have any further questions, please contact:

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