Chapter:	Precautions
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Description:	To avoid damages in case of boiling, the system must be able to comprehend such occurrences. This is done partly by installing several safety components and partly by proper dimensioning.
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Introduction

Since the energy supply in a solar district heating plant cannot be controlled as in an ordinary district heating plant, it is necessary to consider that “extreme” temperature levels may damage the system in case of:

- Freezing
- High stagnation temperature (approx. 200 °C)

Normally antifreeze liquid is used as solar collector fluid in order to avoid freezing. This is explained in fact sheet 7.1 *“Solar collectors”*.

The necessary precautions in terms of avoiding damages due to high temperatures are described in the following sections.

Safety valve

A safety valve must be installed in order to release the pressure by letting some or all of the fluid out of the loop if necessary. A collecting vessel must be able to contain all overflowing liquid since it is normally not allowed to pour the most commonly used solar collector fluids into a drain.

Each heat source must be equipped with directly connected safety device. This means that the piping between the collectors and the safety valve must not contain any closing elements. The safety valve should resist extreme temperature conditions attainable in the system, especially the highest temperature that can occur (stagnation temperature). Important is also resistance to the collector fluid.

The flow cross-section of the safety valve is calculated by equation 8.2.1 below [1]:

$$S_0 \geq \frac{P_p}{\alpha_w \cdot K} \qquad \text{(eq. 8.2.1)}$$

where

S_0:	Cross section of safety valve	[mm^2]
P_p:	Heat performance of determined collector array	[kW]
α_w:	Safety valve outflow coefficient (specified by the valve manufacturer)	[-]
K:	Pressure dependant coefficient interpolated from table 8.2.1	[kW/mm^2]

Table 8.2.1. Pressure dependant coefficient used in equation 8.2.1. [1]

Pressure [kPa]	50	100	150	200	250	300	400	500	600	700
K [kW/mm^2]	0.5	0.67	0.82	0.97	1.12	1.26	1.55	1.83	2.10	2.37

If the expansion vessel(s)* can contain all the solar collector fluid, they will automatically fill up the system when the pressure is decreased, but this solution is normally too expensive for large systems.

Handling stagnation

Stagnation may occur in case of

- power failure
- pump failure
- overheated buffer storage
- too low heat demand.

In that case, the temperature in the solar collectors may reach > 200 ℃. Since the fluid does not circulate in the solar collector loop, and therefore is not cooled, it boils inside the collectors which may cause damages if the pressure becomes too high. The boiling point is highly dependent on pressure as shown in figure 8.2.1. It is only slightly dependent on the glycol concentration† and this does not have a large effect for the concentrations normally used (below 50 %).

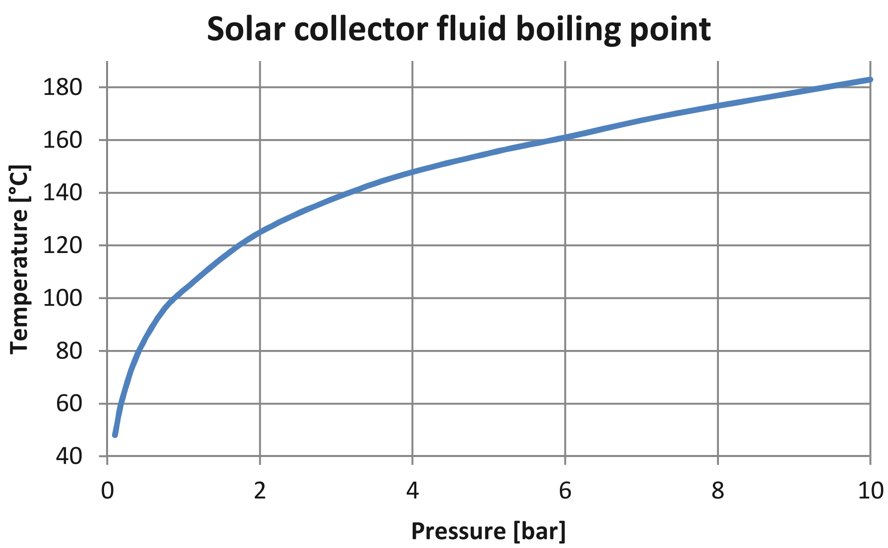

Fig. 8.2.1. Boiling point as function of pressure for a glycol concentration of 40 % [2].

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* *The expansion vessel is described in fact sheet 8.1 "Temperature variations".*

† *Slightly higher boiling point with higher glycol concentration.*

A stand-by backup pump can avoid “blow offs” where the solar collector fluid is forced out of the pipes through the safety valve resulting in the need for filling the plant, i.e. lost energy due to downtime. However in case of failure in the electrical power grid, an extra pump will do no good unless it has an autonomic power supply e.g. diesel and a battery supplied control system.

Coping with high pressure

The system must be able to withstand pressure levels which can occur in case of stagnation. For large systems it can be a challenge to ensure that the pressure does not exceed the tolerable limit since the boiling does not start simultaneously. If steam builds up in the collector furthest away from the safety valve, the pressure increase due to evaporation may be larger than the decrease due to liquid spilling into the containment vessel because of the delay caused by the liquid blocking the way for the steam. When there is a clear passage for the steam to the safety valve, the pressure is quickly decreased. Collectors for large systems are typically tested at pressure levels up to 8 or 10 bar and both the collectors and all pipes between collectors and safety valve shall be dimensioned in such way that pressure in collectors and pipes will not exceed maximum allowed pressure if boiling occurs. It is important to make sure that steam coming from the containment vessel cannot endanger personnel.

Good emptying behaviour

One way to handle stagnation is to make sure the liquid is forced out of the collector loop. The collector designs in figure 8.2.2 all have the option of being emptied completely without disconnecting pipes. In case of stagnation, only a small part of the fluid will evaporate thus increasing the pressure and forcing the fluid backwards in the pipes and into a containment vessel.

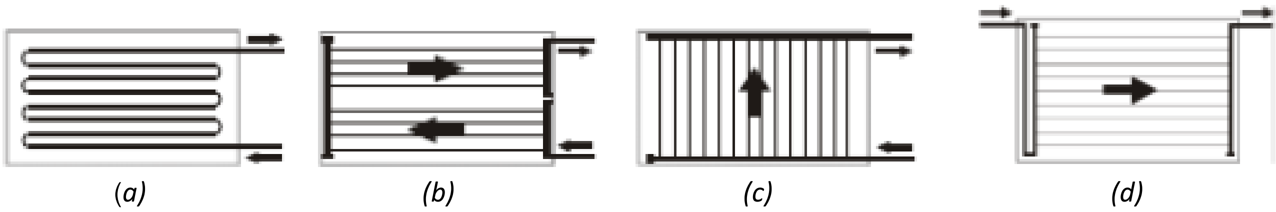

Fig. 8.2.2. Examples of collector design with good emptying behavior. Arrows indicate flow direction at normal operation [3].

In figure 8.2.2-d the manifold on the left side is made so that if stagnation occurs, the fluid in the (horizontal) absorber tubes are forced into the (vertical) manifold on the left and via the bottom up and out of the collector left side. If both inlet and outlet are made as the manifold on the right side of figure 8.2.2-d, the pressure increase from the first small amount of evaporated fluid would only force the liquid in the top part of the absorber tubes backwards through the collector array. A large part of the liquid would be kept inside the rest of the absorber tubes while boiling.

The inlet in the collector in figure 8.2.2-d could also have been made at the bottom, but this would require extra piping *outside* the insulated collector box when connecting several units in serial.

Collectors cannot be made with both inlet and outlet at the bottom since it is necessary to be able to let out trapped air.

Most large systems in Denmark use collectors which simply has a manifold each side and an inlet as the one on the right side of figure 8.2.2 d. In case of a pump failure, most of the fluid will continue to boil inside the collector as long as the irradiation is large enough to keep the temperature above the boiling point or until all the fluid is evaporated.

Studies [4] have shown little or no effect on the collector fluid due to boiling for a small system, but it is necessary to check the collector fluid after boiling to ensure that the pH-value have not decreased making the liquid acidic. Boiling can also cause an exclusion of corrosion inhibitors on walls of pipes in collector absorber. It is recommended to check concentration of corrosion inhibitors in collector liquid to decrease a risk of corrosion in the system. [1]

References

[1] Solární tepelné soustavy (Solar thermal systems), MATUŠKA T. Společnost pro techniku prostředí – odborná sekce Alternativní zdroje energie, 2009.

[2] Based on a data sheet for "Tyfocor® L concentrate for long-term antifreeze and corrosion protection of heating and cooling circuits, solar and heat pump systems" by TYFO.

[3] Stagnation behaviour of solar thermal systems, IEA-SHC task 26, R. Hausner & C. Fink, November 2002.

[4] Solfangerkreds med stor ekspansionsbeholder og fordampning i solfanger ved faretruende høje temperaturer til sikring af solfangervæske og anlæg, Janne Dragsted et al. DTU Byg-Sagsrapport SR-10-04 (DK), May 2010.

The SDH fact sheets addresses both technical and non-technical issues, and provide state-of-the-art industry guidelines to which utilities can refer when considering/realizing SDH plants. For further information on Solar District Heating and the SDHtake-off project please visit www.solar-district-heating.eu.

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