Simple and Safe Solar Heating: A Whole Systems Approach.

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ABSTRACT

By now the rapid growth of the market for solar heating technology has brought about a large number of operating installations across the globe. The systems however still are quite complex in terms of installation and operation. On that account, the question of long-term reliability and minimized maintenance currently attracts substantial attention. The German Solar Energy pioneer Wagner & Co. has invested considerable time and know-how into the development of safe and simplified high-tech solar heating solutions. One example is the SECUSOL® system explained in detail this paper.

(Keywords: SECUSOL, solar energy, solar heating, solar thermal systems, overheating, stagnation)

INTRODUCTION

In Europe and elsewhere the CO_2 emission reductions required in the context of climate protection goals have lead to a strong trend towards solar thermal systems with space heating support, as opposed to systems for domestic water heating only. The goal is to achieve solar fractions above 50%, and consequently the average collector surface area per installation increases. Increased surface area however leads to a higher probability of overheating and stagnation, even in moderate climates. In more southern latitudes like the Mediterranean countries, even small hot water installations regularly are at risk of overheating of collectors and solar circuits.

It is a fact that the installation and set-up of solar thermal systems is no longer the realm of rare solar enthusiasts. Solar long ago become mainstream, and the experience at Wagner & Co. is that more and more plumbers without special training carry out installations.

Another fact is that solar energy systems are spreading in a growing number of countries, where knowledge and experience regarding installation of solar thermal systems has so far only has reached an intermediate level. Although in general this is a very positive development, as a result the effectiveness and reliability of solar energy systems more and more depend on the simplicity of installation and set-up. Yet many current high performance solar heating plants still are quite complex and hence error prone, which can result in many problems during installation, commissioning and operation.

OVERHEATING AND STAGNATION

Overheating during stagnation is one of the most frequently discussed problems. When the heat transfer liquid is exposed to temperatures above 220°C, rapid degradation of the antifreeze that is used in most systems results, which subsequently can lead to damage and eventually failure of the solar circuit. Another problem of overheating is that the vapour forming during stagnation penetrates into the liquid circuit, where it can damage and destroy components like vents, valves, membrane expansion vessels and others.

The solar liquid inside the collector begins to evaporate when the circulation of the heat transfer liquid is stopped and excess solar heat of the collector can no longer be dissipated. This can happen, for example, when heat storage capacity is exceeded and solar loading continues (i.e. during summer time, especially in space heating supporting installations or in southern latitudes, when heat demand is lower than the amount of solar heat delivered). Another common reason is failure of power supply to the circulation pump fails for any reason.

AVOIDING OVERHEATING AND EXCESSIVE VAPOUR FORMATION

Various strategies have been developed and implemented at Wagner & Co. to cope with overheating. The first possibility is to use easily draining collectors to avoid boiling and exposure of the liquid to idle temperatures. Serpentine flat plate collectors in horizontal arrangements feature the most favourable draining characteristics. In many cases, though, the draining characteristics are not optimal for various reasons. Design or space requirements for instance might require a certain orientation.

Hydraulic layouts in larger collector fields make a certain orientation of the collectors necessary due to the connector positions, pressure drop demands that do not allow for serpentine absorbers in multi-collector arrangements, etc. In these cases the solar circuit has to cope with vapour formation. The heat dissipation power of the circuit depends on the heat losses of the tubing. It might be necessary to add a heat dissipation vessel upstream of the expansion vessel as an extra heat dissipation device (see Figure 1).

This heat dissipation vessel protects the expansion vessel and the other components of the solar pumping group against intolerably high temperatures by dissipating the heat of the condensing vapour.

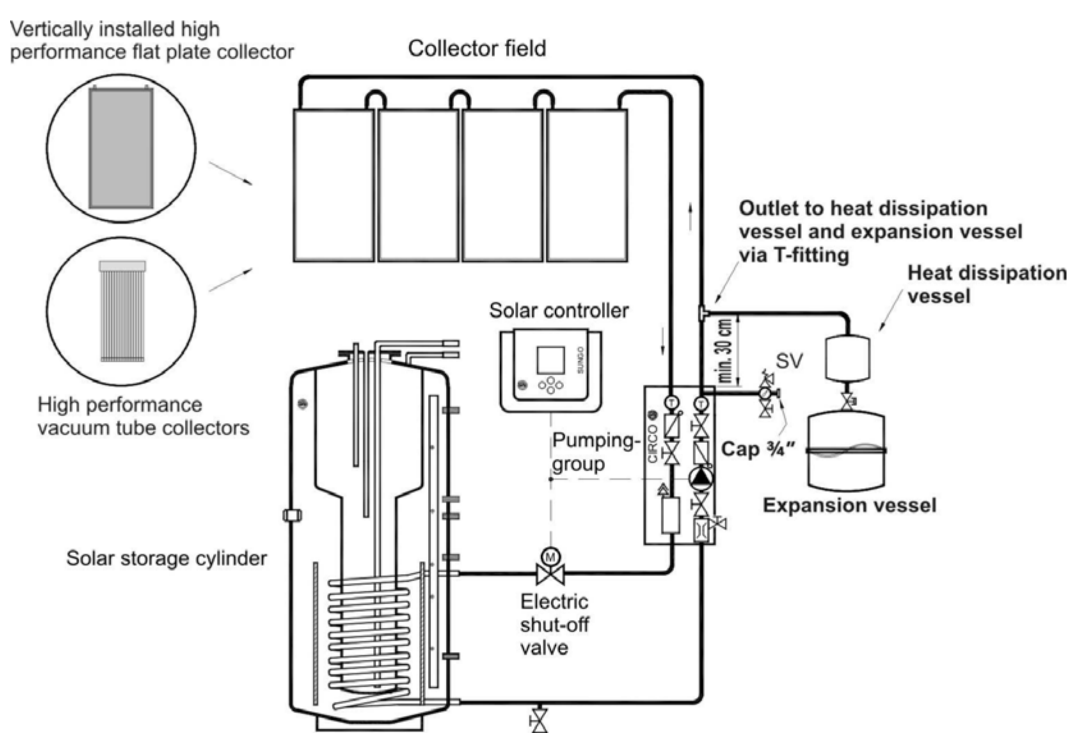

Figure 1: Solar Circuit with Added Heat Dissipation Vessel.

Image Source: Temperatursicherung, Wagner & Co. Publishing, Wagner & Co. R&D, 2007.

The quantity of vapour formation in the collector can be described by the maximum vapour production power. Some existing data showed values from 15 W/m² for serpentines up to 385 W/m² at 4 bar relative pressure for vacuum tubes [1]. The maximum penetration depth of vapour into the solar circuit can be estimated, if the heat losses per length of piping and the heat dissipation performance of a possibly mounted heat dissipation vessel upstream of the expansion vessel are known. The maximum penetration depth of the vapour is reached when the maximum vapour production power equals the heat losses of the tube and the heat dissipation performance of the heat dissipation vessel. Consequently, careful design of piping and heat dissipation vessel guarantees sufficient control of vapour penetration into the piping.

It is important to note that automatic air vents are no longer required and often entirely left out in the sections of the hydraulic circuit prone to vapour exposure. This is necessary to avoid vapour losses. In these sections, it is also inevitable to use fittings and armatures capable of withstanding vapour temperatures.

Reducing the efficiency of the collectors during periods of very high solar irradiation is a further approach to avoid overheating. One possibility is controlling the solar circulation pump in such a way that the solar liquid in the collector reaches the maximum allowable temperature. If the temperature of the heat transfer liquid in the collector is very high, the efficiency drops significantly. Loading the heat storage tank takes much longer, thus reducing the probability of reaching the point of stagnation.

Other possibilities are the use of heat dissipating heat exchangers, for example existing boiler or radiator equipment, during summertime or cooling the heat storage tank during nighttimes. Pumping the solar liquid through the collectors during nighttimes hence radiating the excess heat into the night sky can easily achieve the desired effect.

It is important to mention, that the last approaches are not valid in the case of system failure.

One of the development focuses at Wagner & Co. is the so-called drain-back technology, which applies an entirely different approach to overcome the overheating issue. These types of solar thermal systems, like the Wagner & Co. SECUSOL®, have an intrinsic and fail-proof safety mechanism against overheating, utilizing a self-draining effect during stagnation (Figure 2). The solar circuit is only partly filled with heat transfer liquid. The remainder of the piping and the collector remain air-filled. If the temperature in the collector reaches a certain level, the pump starts pushing the liquid upstream. This movement of liquid displaces the air into a collecting vessel, and the liquid begins to circulate. When the pump stops, the liquid drains back into the collecting vessel by gravity, and the air moves back into the collector. Thus, the heat transfer liquid is removed from exposure to solar heat during stagnation of the solar circuit, avoiding its thermal degradation.

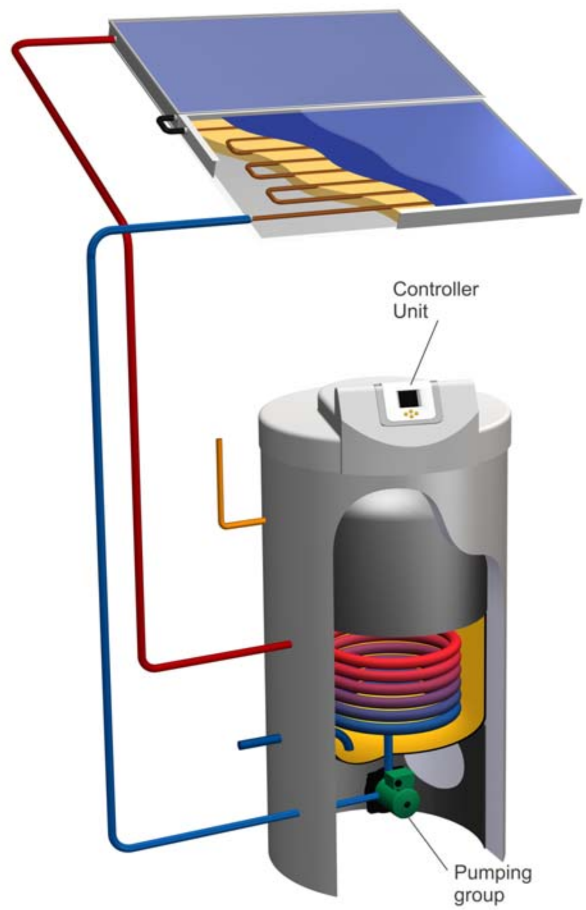

Figure 2: Wagner & Co. Drain-Back System SECUSOL.

Image Source: SECUSOL, Wagner & Co. Advertisement Dept., 2006.

To avoid the antifreeze degradation problem, some drain-back systems operate with pure water. This is only acceptable if it can be guaranteed that the water in the solar circuit is never exposed to freezing conditions. However, experience shows, that in Europe or even northern Africa and the Middle East, this can rarely be absolutely guaranteed. Optimal frost protection therefore only is provided with antifreeze, as used with the SECUS® system. Another advantage of heat transfer liquid with antifreeze is that a continuous hydraulic gradient of the piping is not anymore mandatory (as it is in water-only drain-back installations). As a result common roof passages can be utilized, and the required accuracy of piping installation generally is lower and less error prone.

SIMPLICITY OF INSTALLATION AND SET-UP

Installation and set-up errors often are not noticed. Only highly qualified plumbers are able to guarantee the high level of installation and set-up quality necessary for today's complex solar thermal systems. On the other hand, as mentioned above, non-specialized plumbers carry out an increasing number of installations. An approach to this challenge can be to radically reduce the complexity of current solar thermal installations.

The Wagner & Co., Research and Development (R&D) Department carried out an integrated systems analysis with the declared goal to avoid any device not absolutely necessary and to integrate all functional components in as compact a way as possible. At the same time, clever ideas should be incorporated to improve functionality and reliability without increasing complexity.

Again, we return to drain-back systems. They are intrinsically safe regarding overheating. Drain-back systems do not need any heat traps, because thermo-siphon effects cannot occur. Insufficient deaeration, which occurs sometimes in installations, is no issue in drain-back systems. Air vents are not necessary. The occasionally failing membrane expansion vessels are not required since the collecting vessel or the only partly filled storage tank compensate for the thermal expansion of water.

The SECUSOL® drain-back system by Wagner & Co. (Figure 3) even goes some steps further. The concept of liquid expansion compensation has been implemented keeping simplification in mind. State-of-the-art drain-back systems do have a collection vessel that is normally a separate component of the solar inlet leg. This vessel has to withstand relatively high temperatures and pressures and must be insulated. SECUSOL® works without such a separate vessel. Instead, the diameter of the heat exchanger coil inside the heat storage tank simply was increased so that it can take over the additional function of the collecting vessel.

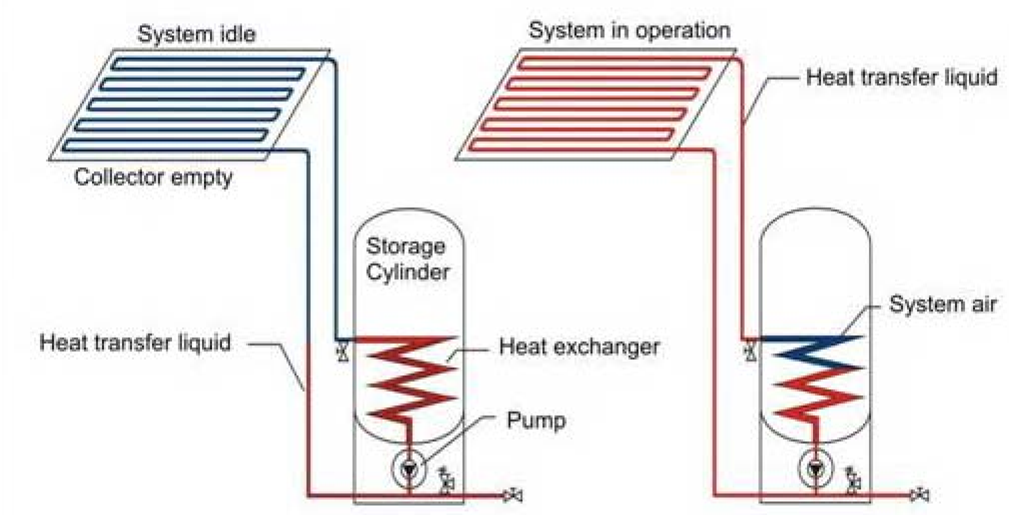

Figure 3: SECUSOL® Drain-Back Working Principle.

Image Source: T. Schabbach et al., Drainback System SECUSOL, OTTI Poster Presentation, Wagner & Co. R&D, 2006.

Integrated collection vessels have been known before, but the simplification of design, which allows using weld-less pipes and avoids the requirement for any additional insulation, are unique features of the SECUSOL® system. Reliability is improved and at the same time production, installation, commissioning, and maintenance are significantly simplified.

An increased heat transfer rate inside the heat exchanger coil was a positive side-effect of integrating the collecting vessel. During operation there is a two-phase flow inside the coil. The liquid moves rapidly and is highly turbulent along the inside surface of the coil, forming a thin layer. This is highly favourable for the heat transfer compared to the relatively slow near laminar flow of the liquid when the coil is completely filled and the inner mass of the liquid contributes very little to the heat transfer.

Investigations by the Institute of Energy Technology, TU Dresden, Germany [2] and a large number of field tests in Spain also have shown that corrosion and cavitations do not pose any problem in the Wagner & Co. SECUSOL® system.

A very high level of pre-assembly and the reduction of the number of required components lead to a significant reduction of installation time. The installation steps related to the pumping group, membrane expansion vessel, and solar controller completely fall away. All of these components are either pre-assembled on the SECUSOL® system or not required at all. The solar circuit of the system is filled by gravity; a filling pump is not necessary. Deaeration and adjustment of the expansion vessel pressure is not needed (Figure 4). Installation time can be reduced by 50% compared to common solar heating installations. In addition, maintenance is simplified.

CONCLUSION

Nowadays there is a strong demand to increase solar fractions to above 50% in solar heating and hot water preparation installations. This results in growing collector surface areas per installation. Possible problems regarding overheating during stagnation can be avoided by considering appropriate installation procedures, even if collectors do not drain perfectly. Improved drain-back systems (for example Wagner SECUSOL®) combine a very high level of reliability in operation and simplicity in installation, set-up and maintenance. The high degree of integration of such a system significantly reduces the required level of installer qualification, installation time and cost, thus, supporting the spread of solar thermal systems.

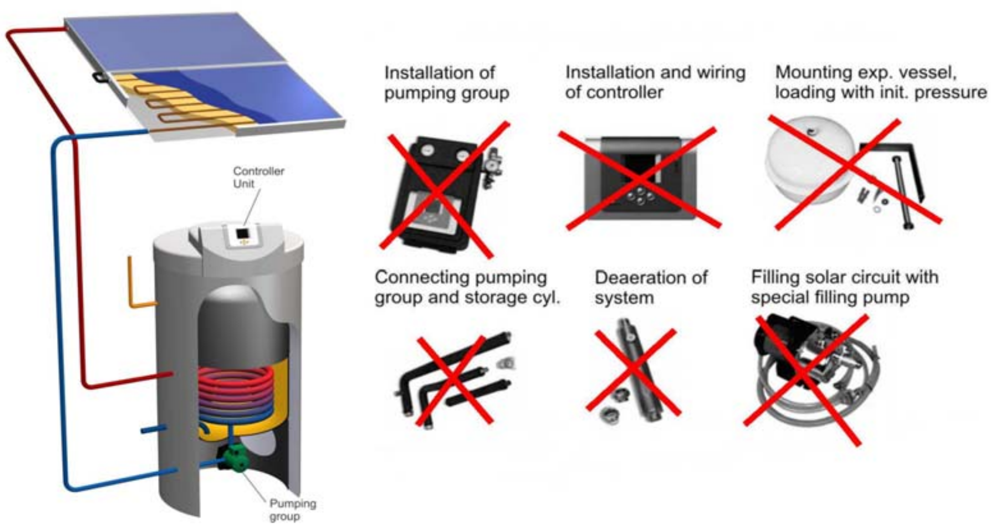

Figure 4: Keep it Simple - Fewer Parts, Fewer Problems, Fewer Costs.

Image Source: Sander, K.: Simplified Drainback Installations, Seminar Presentation, Wagner & Co. R&D, 2008.

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Stefan Thiesen, Ph.D. studied Geography, Physics, and Astronomy in Münster/Germany, London/UK, New York, and Honolulu and earned a Ph.D. in Astronomy focusing on the long term evolution of planetary atmospheres. His research interests are in renewable energy and renewable energy-based water solutions, environmental change, and impact assessment and decision making processes in realms of complexity. Dr. Thiesen is with the R&D Department of Wagner & Co. Solar Technology – a leading solar energy company in Europe (www.wagner-solar.com). He was a keynote speaker on a NATO advanved research workshop in Hammamet/Tunesia on renewable energy-based desalination solutions. He also served as grant reviewer for the National Science Foundation (US) and is also on the editorial board of the "African Journal of Environmental Science and Technology". Dr. Thiesen has published 8 books, including topics in popular science, and over 200 papers and articles.

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