Stagnation of Large Scale Solar Plants

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Abstract

Among the large scale solar plants realized so far, the occurrence of stagnation is generally rare so that no special precautionary measures were taken to re-start the plants quickly and maintenance free. However, when it comes to large scale plants with industrial and commercial applications - which in the future will probably be set up increasingly - frequent cases of stagnation can be expected (e.g. standstills over the weekend, holidays,…) and special, system oriented measures are required to achieve a smooth stagnation behaviour for the plant operator. A concept, many times proven with small scale plants, was adapted to large scale plants. In order to keep significant and temporary steam generating capacities (up to about 130 kW per 1000 m^2 collector surface) in large scale plants under control, an efficient stagnation cooler which runs without auxiliary power was developed and causes a complete condensation of the vaporous heat carrier occurring in case of stagnation. The condensate is temporarily stored in a collecting container and can be pumped back into the system automatically and pressure controlled as soon as the stagnation process is finished. An already existing large scale plant (500 m^2) was later retrofitted with a suitably dimensioned prototype of this stagnation cooler, together with the necessary system adjustment and a measuring system was installed. The measurements showed the efficiency of this cooler principle. Nevertheless, special focus must be put on the arrangement of pipes of the feed and the return lines, as severe steam hammering might occur during the refilling procedure.

1. Introduction

Up until today large scale solar plants were planned for economic reasons in a way that even during the summer the available solar heat gain of the plant did not exceed the usually more or less steady heat requirements of the load. Stagnation only occurred in rare cases of technical afflictions. Respective maintenance effort after a case of stagnation has been accepted. Generally, in case of stagnation, relatively high thermal steam power has to be anticipated, which has to be discharged. Without suitable cooling measures this leads to the partial discharge via a safety device and to losses of vaporous heat carrier [1, 2].

In large scale plants for industrial applications stagnation can occur considerably more often (e.g. process dependencies, standstills over the weekend or company holidays). The requirement is thus that no heat carrier losses occur and that maintenance-free refill must be guaranteed.

2. Investigation of Plants

In the beginning of 2008, 56 large plants with collector areas ranging from about 500 to over 10000 m^2 were known Europe-wide. A questionnaire campaign showed that the majority of the plants were used, dimensioned and run in a way that stagnation hardly ever occur ("none" to "rarely"). At a plant for industrial process heat, stagnation occurred "several times" despite night cooling (a measure to reduce stagnation frequency which, however, leads to a reduction in solar yield and an increase in auxiliary power efforts). In most of the plants, ejected liquid medium is collected in a collecting container and steam losses are accepted. Hereby the refill of the plant is mostly carried out by the staff, rarely automatically by a pressure controlled pump.

3. Stagnation at Small Plants

For smaller solar plants (up to 50 m^2) a stagnation air cooler, working without auxiliary power - in practice repeatedly tested and proven - is used in order to limit the steam volume, 'Fig. 1. '. Heat carrier losses can thus be avoided and an automatic refill of the system is enabled. Investigations showed outputs of the steam leaving the collector from 20 W per m^2 collector area (very well discharging behaviour) up to 130 W/m^2 (very unfavourably discharging), depending on the discharging behaviour of collector and the system. This power has to be emitted before the steam reaches temperature sensitive components of the system (e.g. the membrane expansion vessel – MAG). If heat losses of the feed and the return lines are insufficient, the stagnation cooler [2] can limit the steam expansion. Detailed information about the collector's or systems' specific steam power allows a correct dimensioning of the cooler and the MAG and the activation of the safety valve can thus be prevented.

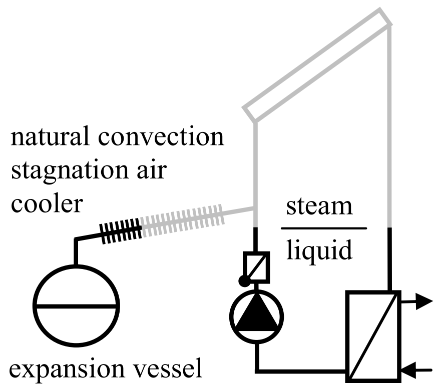

Fig. 1. Underlying hydraulic scheme for the limitation of steam expansion for smaller systems.

4. Further Development of the Stagnation Cooler for Large Plants

This maintenance free concept was adapted for large scale plants, 'Fig. 2. '. The air cooling element has to be replaced by a considerably more effective element that can thus be designed in a much smaller size. The conventional pressure maintenance appliance (preceding vessel and MAG) is only meant for normal operating conditions, i.e. that the expansion of liquid is all it has to carry and can thus be dimensioned in a smaller size. In case of stagnation, an increase in volume caused by the development of steam leads to an increase in pressure (defined by the MAG) up to the point where the response pressure of the overflow-valve is exceeded and the liquid streams into the pressure-less collecting container after a cool-down in the stagnation cooler and stress relief. Later the steam reaches the cooler where it is condensed, further cooled down and also collected in the collecting container. The maximum system pressure is defined by the overflow valve.

As soon as the stagnation process is finished, the heat carrier is pushed out of the MAG and later on pumped back automatically (pressure controlled) out of the collecting container after falling below normal system pressure.

The stagnation cooler contains a tube bundle condenser which is surrounded by the cooling medium water (pressure-less). This cooling medium (decalcified or rainwater) then vaporizes and is released into the outside area via an exhaust steam line. By applying this evaporation cooler, the need of cooling water is reduced to much less than a tenth of continuous flow cooling. If necessary, cooling water is refilled through a level switch. However, the water reservoir in the cooler is dimensioned in a way that one or even more cases of stagnation can be kept under control even without refilling it (security in case of a power breakdown). Also no auxiliary power needs to be available during the period of stagnation.

For this cooler concept a dimensioning program was set-up and a suitable hydraulic integration into the solar circuit designed.

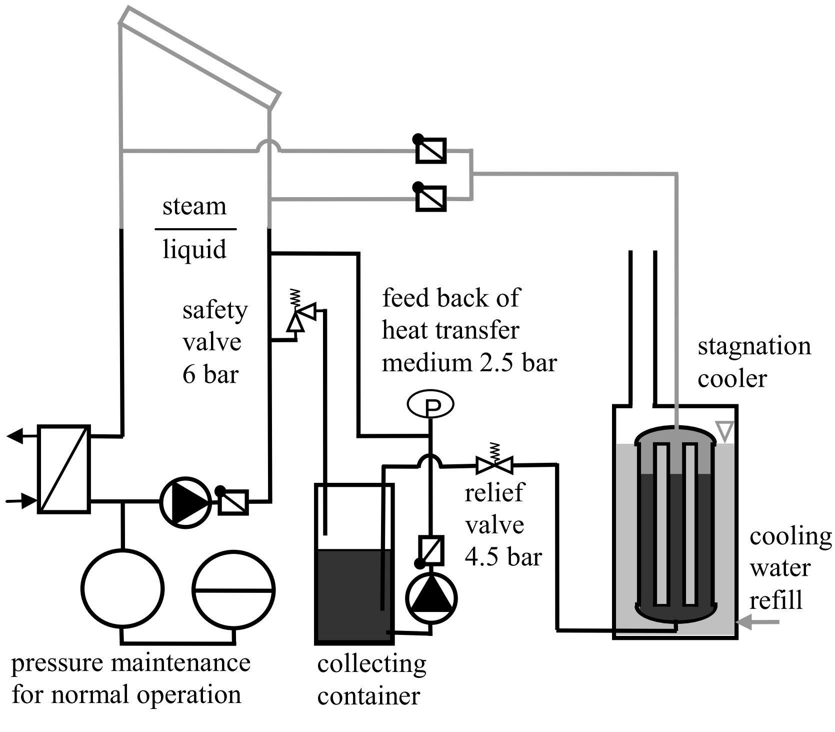

Fig. 2. Underlying hydraulic scheme for the limitation of steam expansion for large-scale thermal solar systems with suggested pressure values, as tested in the trial plant

5. Measurements on a Prototype

An existing large scale solar plant (company S.O.L.I.D., Graz, Grottenhofstrasse, 501 m^2, heat supply of a housing estate) was retrofitted with a suitably dimensioned prototype of this cooler type (company Pink Behälterbau, Langenwang, Austria – 'Fig. 3. ') and a measuring system was installed.

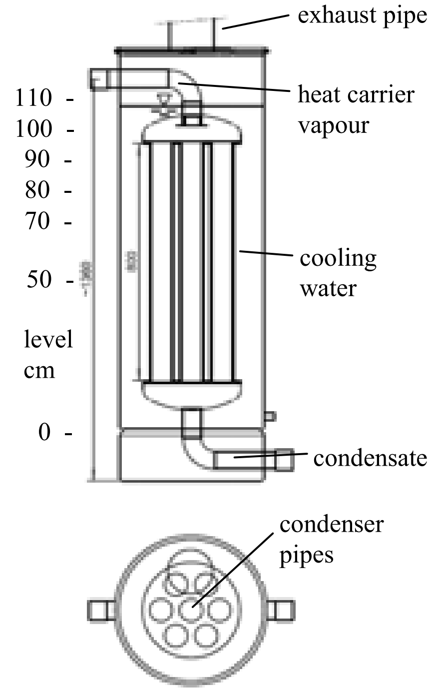

Fig. 3. Prototype of stagnation cooler

Tests with the system showed the principle's functional capability. The expansion of steam was effectively limited by the cooler and sufficient reserves of cooling medium were available to control several stagnation processes without refilling the system.

'Fig. 4. ' shows a measurement of a stagnation process. Noticeable was first the relatively long period from the switching off of the primary circuit pump (11:53 a.m.) until the steam actually reached the cooler (12:38 p.m.). As the MAG was not dimensioned for such a control of stagnation – it is far too big – the connection between the pump and the MAG was closed with a ball valve immediately after switching off the pump. Consequently a quick increase in pressure was observed until the reaction of the overflow valve (11:54:30 a.m.). Almost the entire reservoir of cooling water was brought to boiling temperature by the hot liquid medium streaming through the cooler while simultaneously, with the beginning of the steam condensing (the level of the liquid heat carrier falls below that of the cooling water), the cooling water began to vaporize. Initially in these tests the maximum vaporization power of about 37 kW was reached. It was calculated from the decrease in level of the cooling water reservoir. Altogether 467 l of heat carrier streamed through the cooler and about 14 l of cooling water vaporized.

The cooler was dimensioned to a maximum vaporization capacity of 70 kW. This value results from the maximum specific steam power of about 130 W/m^2 [2] available for the existing collector type. Independently from this kind of steam volume limitation it showed that when the feed and the return lines are not guided optimally, severe steam hammering can occur during refill. Therefore a proper pipe line is required inclining consequently in direction of the cooler.

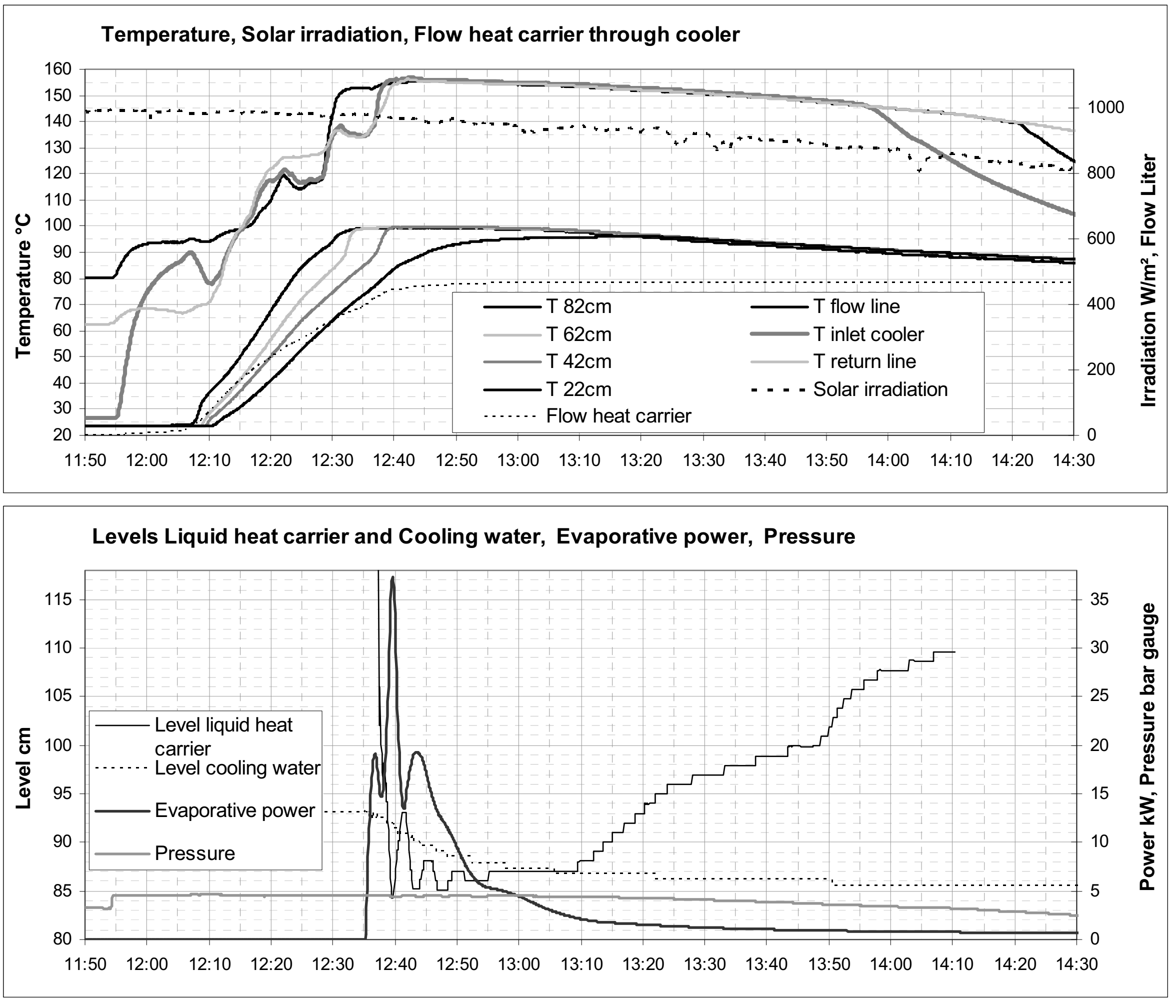

Fig. 4: Measuring of a stagnation process at a radiation power of about 960 to 990 W/m^2, the primary circuit pump was shut off at 11:53 a.m.. Indicated examples: T 82 cm – temperature of cooling water at a level of 82 cm - see ‘Fig. 3. ’, T inlet cooler: feed of heat carrier shortly before cooler.

Through the open collecting container it is possible that minor amounts of air can enter the plant during automatic refill. Thus, the integration of simple air separators seems practical. Regarding the mentioned test series, however, no noticeable entry of air was observed.

Depending on the frequency of stagnation processes and the quality of the (scaled) cooling water, the cooler should be controlled and possibly cleaned from time to time.

References

[1] C.Fink, R.Hausner, (2001). Final report “Stagnation Technology for Thermal Solar Systems”, program line CRAFT JOULE, Task b1 – B8, Gleisdorf.

[2] C. Fink, R. Hausner, W. Wagner, R. Riva, F. Hillerns (2003). Final report “Entwicklung von thermischen Solarsystemen mit unproblematischen Stagnationsverhalten, programme line „Haus der Zukunft“, BMVIT Austria, Gleisdorf.