HI-SMART: HIGHER EDUCATION PACKAGE FOR NEARLY ZERO ENERGY AND SMART BUILDING DESIGN

MODULE #4

CHAPTER 7: SOLAR THERMAL ENERGY UTILISATION

Co-funded by the Erasmus+ Programme of the European Union

UNGLAZED, TRANSPIRED SOLAR AIR HEATERS

Unglazed, transpired solar air heaters are of simpler construction, compared to modular solar air heaters. As Figure 4.7.1 shows, a dark, perforated metal shield is fixed onto a building's façade in a given distance. This metal shield is the absorber.

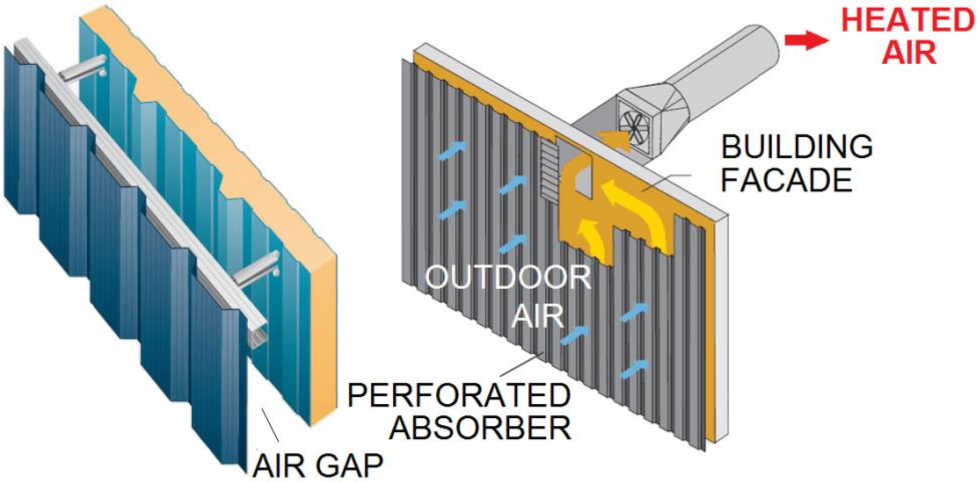

Figure 4.7.1: Construction and operational principle of a transpired solar collector [1][2]

Fresh outdoor air transpires the absorber, rises in the gap and finally a fan forwards it to the building's ventilation system. As seen before, a solar collector's efficiency is limited by optical and thermal losses. Unglazed solar air heaters have the advantage of having minimal optical losses due to the lack of transparent cover, just as previously described for solar pool heaters. They also reach high efficiency at lower operational temperatures, as the temperature difference is little, resulting in low thermal losses, too.

Based on the construction of unglazed, transpired solar air heaters, they can only warm up outdoor air. A thin layer of warm air develops at the outside of the absorber, which is being sucked in through the perforations. While rising up in the gap between absorber and building façade, the air gets heated further. This means, that both sides of the absorber takes an active part in the heat transfer process. Furthermore, the convectional losses of the building envelope can be regained on the surfaces where the air heaters are installed.

Suitability of Solar Air Heaters to Different Building Types

The efficiency of a solar air heating system depends very much on the type and use of the building in which it is installed. Influencing factors are internal heat loads, passive solar gain, as well as heat and fresh air demand. Low internal heat load and solar gain are advantageous with a possible high fresh air demand, so that the benefits of the solar air heating system can be realized within a short time.

In residential buildings, especially in low-energy ones, mechanical ventilation supplies the necessary amount of fresh air. The ventilation system can be supplemented with solar air heaters, in order to reduce the heating costs, first of all, if no heat recovery unit was previously installed.

In office buildings both the internal heat load, as well as the solar gain can be high, due to the heat emission of the employees and the high glazing rate of the facades. This is why office buildings do not ensure optimal conditions for solar air heaters. Systems heating fresh outside air can directly reach high efficiency due to the high fresh air demand of employees.

Industrial buildings ensure optimal conditions for the operation of solar air heaters. The high spaces usually have a low glazing rate, resulting in low heat gains. Production processes often demand a high rate of fresh air in ventilation, providing good use of a solar air heater system.

Depending on the nominal transpiration of the transpired solar collector (TSC) over one m^2 of area, different operational strategies can be determined. High volume flow systems provide lower temperature rise, but they enable the collector to reach high efficiency due to low heat losses from the absorber. Low volume flow systems reach higher temperature rise but the collector efficiency stays lower.

One could think that in the lack of transparent glazing, the TSC has remarkable thermal losses due to convection to the exterior. According to Kutscher et al. [3], assuming homogenous suction on the surface of the absorber, one can state that the suction stabilizes the boundary layers on the external side of the absorber, reducing the effect of convective losses solely to the collector edges. This means that the heat of the external boundary layer is being utilised by the system before losses would occur. Therefore, for large collector surfaces the convective losses are negligible and wind losses remain small, too. Kutscher et al. [3] describe that to ensure little impact of wind:

- the suction face velocity should be preferably 0.04-0.05 m/s, but at least 0.02 m/s,
- at least 25 Pa pressure drop is to be obtained across the perforated plate, and
- the wall should be designed to have uniform flow through itself.

The flow rate through the surface of the TSC has to be kept between 18-180 $m^3/(h \cdot m^2)$ to ensure stable operation. Three air heating strategies can be defined by choosing the appropriate airflow:

- high temperature rise in the range of 18-54 $m^3/(h \cdot m^2)$
- standard operation in the range of 54-108 $m^3/(h \cdot m^2)$
- high air volume in the range of 108-180 $m^3/(h \cdot m^2)$

High-flow TSC systems perform much better than low flow ones, as the efficiency can reach its highest values when high flow is cooling the absorber, utilising the most of its heat, reducing all kinds of thermal losses. In Figure 4.7.2 one can see that for a given wind speed the collector efficiency only depends on the air flow rate, which underlines the negligible impact of convective losses depending on ambient temperature.

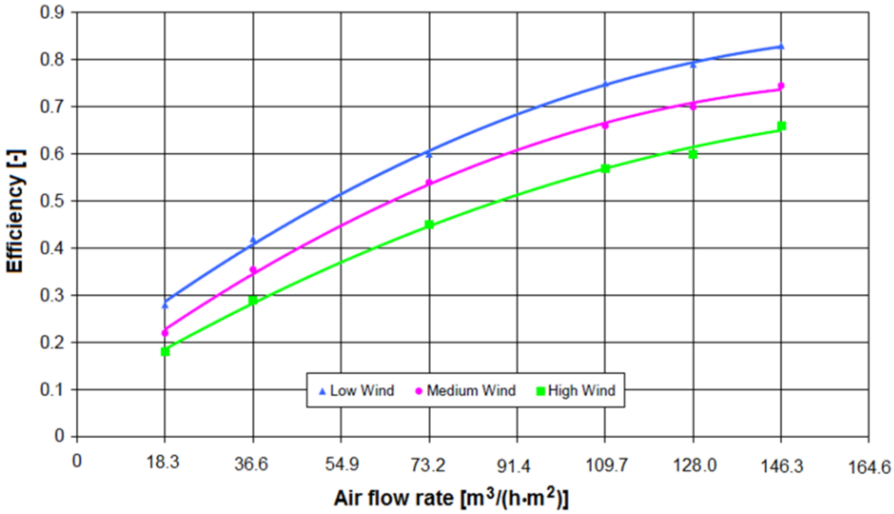

Figure 4.7.2: TSC efficiency as a function of the transpiration rate [4]

With rising transpiration rate the heat exchange effectiveness drops, as the air cannot reach as high temperatures as if lower heat flow would transpire the plate. Temperature rise as a function of solar radiation with transpiration rate and wind speed as parameters is illustrated in Figure 4.7.3.

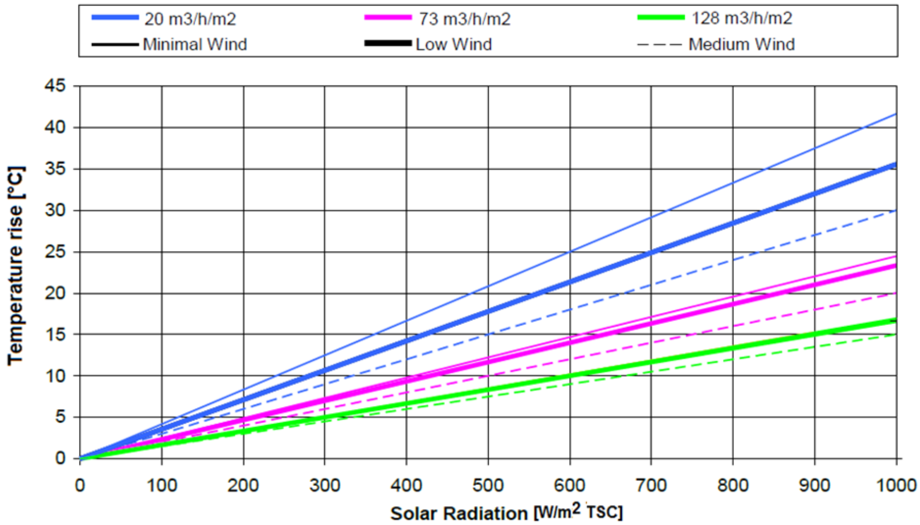

Figure 4.7.3: TSC temperature rise as a function of solar radiation [4]

Transpired solar collectors are available in glazed and unglazed constructions. Glazing reduces the convective losses that would occur between the absorber plate and the ambience, but creates additional optical losses. The choice of the glazing depends on the operational and ambient temperatures. In case high temperature rise is necessary, or the installation is to be set in cold environment, a two-stage transpired solar collector can be applied. This consists of a first stage of a conventional TSC, after which at a higher section of the collector a second perforated absorber is transpired behind a polycarbonate glazing. This enables the airflow to reach higher temperatures or resist to colder environment.

REFERENCES

[1] “tatasteel.com.” [Online]. Available: tatasteel.com.

[2] “ecobuildtrends.com.” [Online]. Available: ecobuildtrends.com%0A.

[3] C. F. Kutscher, C. B. Christensen, and G. M. Barker, “Unglazed Transpired Solar Collectors: Heat Loss Theory,” *Journal of Solar Energy Engineering*, vol. 115, no. 3. p. 182, 1993, doi: 10.1115/1.2930047.

[4] SAHWIA, “Solar Air Heating World Industries Association.” [Online]. Available: http://sahwia.org/. [Accessed: 15-Oct-2018].

Co-funded by the Erasmus+ Programme of the European Union