EXTENSION OF THE CTSS TEST METHOD TOWARDS SOLAR COOLING SYSTEMS

Patrick Frey, Harald Drück and Hans Müller-Steinhagen

Institute for Thermodynamics and Thermal Engineering (ITW), University Stuttgart,

Pfaffenwaldring 6, 70550 Stuttgart, Germany,

frey@itw.uni-stuttgart.de

Abstract

Due to the worldwide increasing demand for cooling and the fact that cooling requirements of buildings and high solar radiation largely coincide, the next evolution step of solar thermal technology are solar cooling systems and in particular so-called SolarCombiPlus systems. These systems provide domestic hot water, space heating and space cooling. Cooling is performed by means of a thermally driven sorption chiller integrated into the system. To support the market entry and to enhance the market penetration of solar cooling systems, it is necessary to have standardised procedures for the overall assessment of such systems. This requires both, performance test methods as well as procedures for the determination of the overall environmental impact. In order to develop the required testing and assessment procedures for solar thermal cooling systems and thermally driven heat pumps (i.e. heat transformers), the project "SolTrans" was started at ITW in 2008. Due to the broad spectrum of locations for the operation of solar cooling and SolarCombiPlus systems and the widely different system designs of solar cooling and SolarCombiPlus systems, a component based test approach, such as the CTSS-method (component testing - system simulation) was found to be the most promising approach.

1. Introduction

To-date, solar thermal collectors are mostly used in systems for domestic hot water preparation and space heating. Due to the worldwide increasing demand for cooling and the fact that cooling requirements of buildings and high solar radiation largely coincide, the next evolution step of solar thermal technology are solar cooling systems and in particular so-called SolarCombiPlus systems. These systems are solar combisystems which provide domestic hot water, space heating and space cooling. Cooling is performed by means of a thermally driven sorption chiller integrated into the system. The performance testing of solar domestic hot water and solar combisystems is based on the CTSS-method (Component Testing and System Simulation) already standardised in CEN/TS 12977 series. Up to now there exists no standardised performance test method for solar cooling or SolarCombiPlus systems. The reason therefore is that standards are always developed with a certain time delay compared to the development of products and systems. This delay may be a barrier for the new products to enter the market, as no testing and certification is possible - or existing standards do not express the benefits of the new products. To remove market barriers and to enhance the market penetration of solar cooling systems and SolarCombiPlus systems, the availability of standardised procedures for the overall assessment of such systems is necessary. This requires both, performance test methods as well as procedures for determination of the overall environmental impact (i.e. LCA: Life Cycle Assessment).

2. The project “SolTrans”

In order to develop the required testing and assessment procedures for solar thermal cooling systems and heat pumps (i.e. heat transformers), the project “SolTrans” was started at ITW in 2008. The main target of this project, which is partly funded by the German Ministry of Economy and Technology (BMWi), is to develop and define testing methods for small-sized thermally driven sorption chillers and heat pumps.

For this reason a new test facility is being developed and installed at ITW, University of Stuttgart. This test facility is designed for performance testing of small thermally driven sorption chillers with a cooling power up to approximately 20 kW. The new test facility will consist of three separate modules, i.e. three circuits for hot water, cooling water and cold water. Hence it will be possible to emulate solar heating, recooling and the space-cooling load. To be able to simulate applications using cold water temperatures below 4°C the cold water module will be prepared to run with brine as well. To provide the possibility of testing the behaviour of thermally driven sorption chillers or heat pumps under dynamics conditions the inlet temperatures and flow rates of all modules can be adjusted computerised independently from each other over a wide range. Hence the specific test can be performed automatically.

The performance testing for custom built solar thermal systems is based on the CTSS-method already standardised in CEN/TS 12977 series for solar domestic hot water and solar combisystems. Since up to now no similar standard is existing for solar cooling systems one main aspect of the activity is to extend the CTSS-method towards to solar cooling and SolarCombiPlus systems. As one of the key aspects, this activity requires the development or modification of numerical models for thermally driven heat transformers in such a way that they can be used to describe the thermal behaviour of the entire solar cooling or SolarCombiPlus system as required for annual performance prediction.

Furthermore the validation of the developed numerical models for thermally driven heat transformers and of the extended CTSS-method is essential. Therefore three solar thermal cooling systems will be monitored in-situ. For all the three plants a comprehensive and unified monitoring procedure, which has been developed within the frame of the international project – IEA SHC Task 38 “Solar Air-Conditioning and Refrigeration” – under the auspices of the International Energy Agency (IEA) Solar Heating and Cooling Program (SHC) will be used [1,2]. On the basis of detailed in-situ measurements it will be possible to validate the developed numerical models for thermally driven heat transformers and the extended CTSS-method by comparing the measured data with the results of simulations carried out by using measurement data as input values.

Standardised procedures for the overall assessment of SolarCombiPlus systems require both, performance test methods as well as procedures for determination of the overall environmental impact (i.e. LCA: Life Cycle Assessment). For this it is also intended to elaborate a method for the determination of the overall environmental impact of thermally driven heat transformers within the “SolTrans”-project. The main elements of the “SolTrans”-project are listed below:

- Extension of the CTSS-method towards solar cooling and SolarCombiPlus systems
    - Development and definition of standardised test procedures
    - Development or modification of numerical models for small-sized thermally driven heat transformers
- Construction of a test facility for small-sized thermally driven sorption chillers and heat pumps
- Validation of the extended CTSS-method by in-situ measurements

- Life Cycle Assessment: Development of methods for determination of the overall environmental impact of thermally driven heat transformers

3. Testing according to the CTSS-method

One established procedure to determine the performance of solar thermal systems is the CTSS-method (Component Testing – System simulation) already standardised in CEN/TS 12977 series for solar domestic hot water and solar combisystems. In general, the solar thermal system does not need to be installed as a whole for testing because this test method is based on component testing and system simulation. Due to this, the application range of the CTSS-method is very flexible because of its component-oriented approach. Hence, it is possible to apply the CTSS-method on nearly every system configuration. Another important advantage of the CTSS-method is that the thermal performance of the tested systems can be easily determined for any arbitrary boundary conditions such as weather and heating/cooling load since this is done by numerical system simulations only.

3.1 Component testing

To apply the CTSS-method first of all the main components of the solar thermal system (the collector, the store(s) and the controller) are being tested separately (see table 1). The aim of the component tests is the determination of all relevant component parameters for the detailed description of the thermal behaviour of the individual components. Therefore, numerical models to describe the dynamic behaviour of the specific components are required. Parameters of this models are determined by means of parameter identification using measuring data from several test sequences of the component testing.

Performance test methods for solar collectors

The aim of performance testing for solar collectors according to EN 12975-2 is the determination of characteristic parameters describing their thermal behaviour. Knowledge of these parameters is essential for prediction of the annual energy output of the collector as well as of the whole system with the collector as a component. All data as listed below should be determined:

- standard collector efficiency parameters such as conversion factor and heat loss coefficients
- collector heat capacity
- incidence angle modifier for beam and diffuse irradiance (biaxial, if relevant)
- wind speed dependence of the collector heat loss coefficients (for unglazed collectors only)
- influence of flow rate, if relevant
- influence of collector tilt angle, if relevant

Performance test methods for stores

The store(s) should be tested in accordance with EN 12977-3 (solar water heater stores) or CEN/TS 12977-4 (solar combistores), respectively. Thereby all data for simulation of the thermal behaviour of the store(s) as listed below should be determined:

- effective volume of the store
- heat capacity
- heat loss rate
- heat transfer rate of the immersed heat exchangers

- parameters characterising the thermal stratification inside the store
- characteristic vertical positions of the connections for direct charging and discharging as well as of the temperature sensors used for controlling the system

Performance test methods for control equipment

With the introduction of CEN/TS 12977-5, performance test methods for control equipment an important step towards testing of multi-function controllers was made. For the first time a test and evaluation procedure for a comprehensive examination of controllers and control equipment for thermal solar systems is available. The new test procedures afford a reliable determination of control parameters that will serve as an excellent basis for testing advanced solar domestic hot water systems and solar combisystems and solar cooling systems based on the CTSS-method. The method described in CEN/TS 12977-5 was already successfully applied to determine controller parameters for system simulations and performance predictions using TRNSYS (Transient system simulation programme). With the new method and test facility which was developed at ITW, a powerful tool for testing different kinds of controllers, not only for solar applications, is provided. In principle the method can be extended to nearly every kind of controller, sensor and various controller outputs. Test sequences can be adapted to any specific control algorithms, particular options or details to be investigated. All algorithms can be examined with a high degree of accuracy and reproducibility. [3]

Table 1: Titles of European solar thermal standards at present (relevant for the CTSS-method)

Number	**Title "Thermal solar systems and components - …"**
EN 12975-1:2006	Collectors – Part 1 – General requirements
EN 12975-2:2006	Collectors – Part 1 – Test methods
CEN/TS 12977-1:2010	Custom Built Systems- Part 1 – General requirements for solar water heaters and combisystems
CEN/TS 12977-2:2010	Custom Built Systems- Part 2 – Test methods for solar water heaters and combisystems
EN 12977-3:2010	Custom Built Systems- Part 3 – Performance test methods for solar water heater stores
CEN/TS 12977-4:2010	Custom Built Systems- Part 4 – Performance test methods for solar combistores
CEN/TS 12977-5:2010	Custom Built Systems- Part 5 – Performance test methods for control equipment

3.1 System simulation

The main aim of the component tests is a detailed determination of all relevant component parameters. Based on these component parameters the annual performance of the whole system can be calculated for defined boundary and reference conditions (meteorological, load profiles) by means of a numerical simulation of the whole system. Therefore together with the hydraulic scheme of the system and the control strategies the parameters have to be implemented in a detailed dynamic and component based system simulation program like TRNSYS.

In summery Figure 1 shows the scheme of the CTSS-method according to CEN/TS 12977.

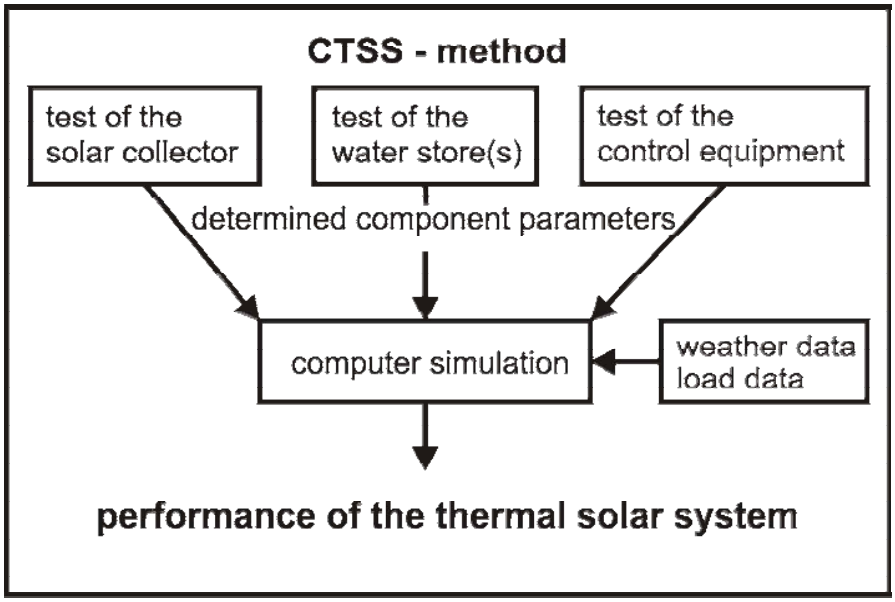

Fig. 1: Scheme of the CTSS-method according to CEN/TS 12977

4. Extension of the CTSS-method towards solar cooling systems and SolarCombiPlus systems

Figure 2 shows how the scheme of an extended CTSS-method applicable to solar cooling systems and SolarCombiPlus systems may look like in general. The difference to the scheme of the present version of the CTSS-method according to CEN/TS 12977 (see Fig. 1) is that there will be one maybe even two more component tests for the cold medium production sub-system in the extended method. It will be indispensable to add one component test for thermally driven sorption chillers and if necessary another one for the recooling system (cooling tower, borehole or other heat sinks).

For the extension of the CTSS-method towards solar cooling systems the following steps are necessary:

- Decision which performance parameters will be required for the assessment of thermally driven sorption chillers (and for the recooling system)
- Development or modification of numerical models for thermally driven sorption chillers (and for recooling system)
- Validation of the numerical models
- Development, implementation and validation of performance test methods for the new components
- Validation of the extended CTSS-method
- Integration of the extended CTSS-method in a revised version of CEN/TS 12977 series

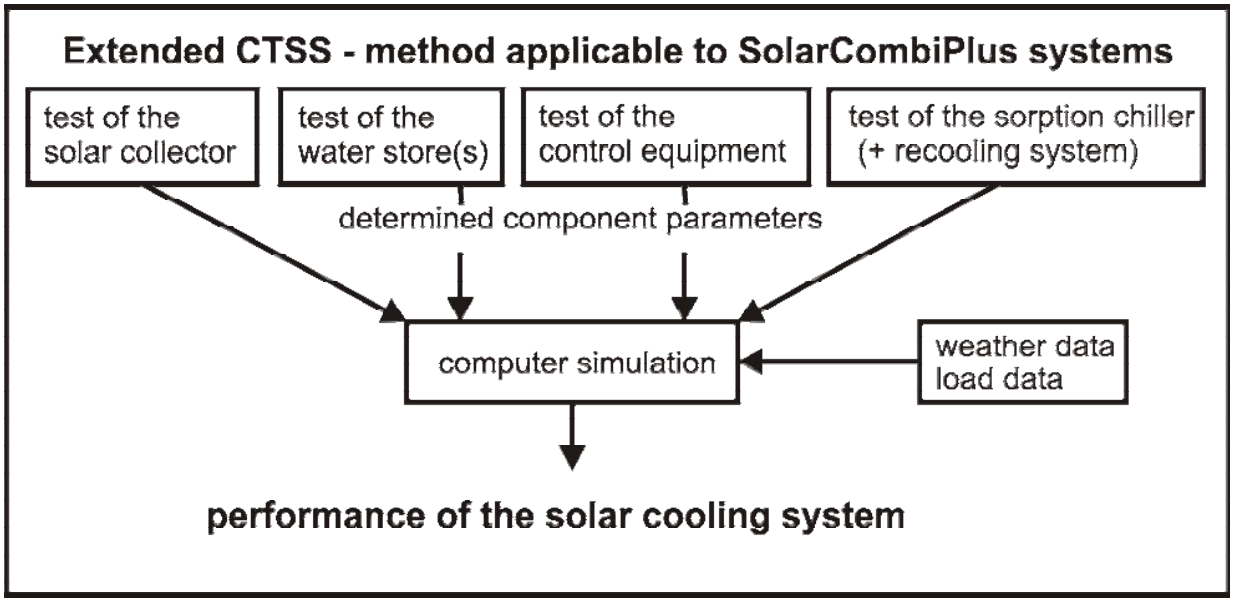

Fig. 2: Scheme of the extended CTSS-method applicable to solar cooling systems (proposal)

5. Conclusions and Outlook

To support the market entry and to enhance the market penetration of solar cooling systems and in particular so-called SolarCombiPlus systems standardised procedures for the overall assessment of such systems are indispensable. This requires both, performance test methods as well as procedures for determination of the overall environmental impact. Due to the fact that one established procedure to determine the performance of solar thermal systems is the CTSS-method already standardised in CEN/TS 12977 series, an extension of this method applicable for solar cooling systems and SolarCombiPlus systems was found to be the most promising way. For this reason the project "SolTrans" (Solar thermal heat transformers – performance testing and overall assessment), which is partly financed by the German Ministry of Economy and Technology (BMWi), was initiated at ITW in 2008. By the end of the project, an extended and validated CTSS-method applicable for solar cooling systems and SolarCombiPlus systems will be available. This method will serve as a basis for the extension of European standards related to performance testing of solar cooling systems. Appropriate standards are a prerequisite for a deep market penetration and for support programmes. In this way the spread of solar cooling and SolarCombiPlus systems can go hand in hand with the build up of important solar thermal markets e.g. in Spain, France and Italy [4,5].

Acknowledgements
The SolTrans project receives funding from the German Ministry of Economy and Technology (BMWi) under the grant number 0327454A and managed by PtJ (Projektleiter Jülich / Project Management Jülich). The sole responsibility for the content of this document lies with the authors.

References

[1] W. Sparber et al.: Unified Monitoring Procedure and Performance Assessment for Solar Assisted Heating and Cooling Systems, Proceedings of EuroSun 2008, Lisabon, Portugal

[2] http://www.iea-shc.org/task38/index.html

[3] M. Peter, H. Drück: Testing of controllers for thermal solar systems, Solar Energy 82 (2008), 676-685

[4] European Solar Thermal Industry Federation - ESTIF: Solar thermal markets in Europe, Trends and statistics, 2005, Bruxelles

[5] A. Troi et al.: Solar Combi+: Identification of most promising markets and promotion of standardised system configurations for small scale solar heating & cooling applications, Proceedings of EuroSun 2008, Lisabon, Portugal