Performance Testing of Solar Combisytems

Comparison of the CTSS with the ACDC Procedure

A Report of IEA SHC - Task 26

Solar Combisystems

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by

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A technical report of Subtask B

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1 Abstract

The performance of solar thermal systems for combined hot water preparation and space heating, so-called ‘Combisystems’, can be determined by applying two different test procedures. According to the CTSS-procedure (component testing – system simulation), which has been further developed within a two years lasting German project (“Kombianlagenprojekt”) by the ITW together with partners from industry and the DFS, the components collector, store and controller are being tested separately.
Besides, in the frame of the work done by the IEA SH&C Task 26 (Solar Combisystems), a new test procedure, the so-called ACDC procedure (annual calculation – direct comparison) is being examined. Here, the combisystem is almost completely set up and operated during a period of several days according to a well defined test sequence.

In the following report, both procedures are briefly described and the results obtained for a combisystem (with two different collector areas) which has been tested according to both procedures, will be presented and discussed.

2 The tested combisystem

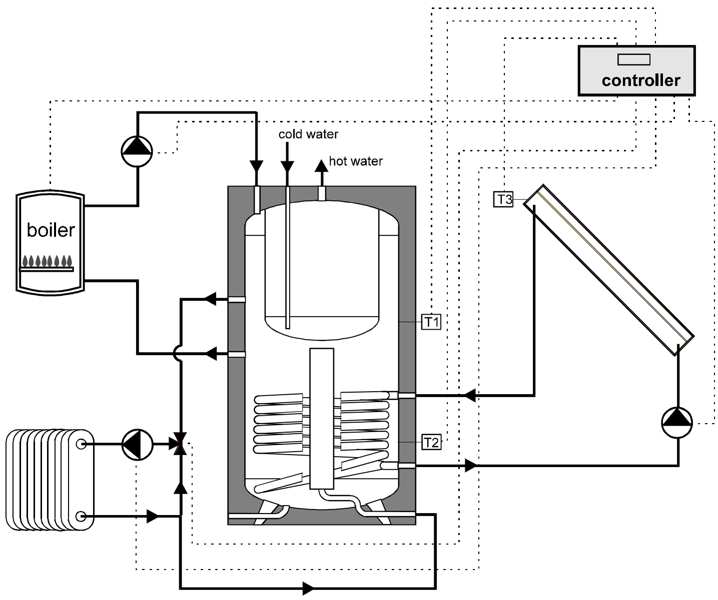

Figure 1: Scheme of the tested combisystem

The combisystem chosen for the comparison of the test procedures is a so-called ‘tank-in-tank’ - system (see Fig. 1). The combistore (nominal value 600 l) is also operated as a buffer for the space-heating system. The heat gained by the collectors is transferred to the store via an immersed heat exchanger in the bottom of the store. The return-line of the space-heating loop is connected to the store via a device which allows for stratified charging.

3 Testing according to the CTSS Procedure

When applying the CTSS-procedure, the thermal performance of the collector (according to EN 12975-2) and the store (according to ENV 12977-3) is determined and the function of the controller is checked (according to ENV 12977-2, Annex A). The aim of the thermal performance tests of the collector and store is the determination of characteristic parameters which allow – in connection with a numerical calculation model – a detailed description of the thermal behaviour of the components. Based on these parameters, the performance of the combisystem can be determined for defined reference conditions (meteorological, load profiles) by means of annual system simulations.

4 Testing according to the ACDC Procedure

For testing the combisystem according to the ACDC procedure [1] (which is still under development), the system is completely set up (except the collectors) and then it is operated for a period of eight days according to a well defined test sequence. In order to be independent from the weather and to achieve reproducible test conditions, the energy gain from the ‘collectors’ is simulated by a so-called ‘collector emulator’. This collector emulator consists of an electrical heating element with variable power output.
The discharging of the combistore with regard to the space heating and domestic hot water load is also controlled by the test facility.
For heating the auxiliary part, a separate gas or oil boiler is used.

The first two days of the test sequences are used to achieve a thermal condition inside the store, that is similar to the one at the end of the complete sequence or year respectively. This is necessary in order to ensure that the internal energy inside the store is the same at the beginning and the end of the ‘core phase’.
The following six days (called “core phase”) represent two typical winter days, two typical summer days and two days typical for spring and autumn (average conditions of each season). During the test cycle, all heat quantities transferred to or removed from the combisystem (combistore) are recorded. On the basis of the measured quantity for the auxiliary heat ($Q_{aux,test}$) transferred to the store during the core phase, it is theoretically possible to compare different combisystems with regard to their thermal efficiency (DC procedure). In order to determine the annual energy savings in comparison to conventional heating system, the annual auxiliary energy consumption ($Q_{aux,y}$) is calculated for a whole year (ACDC Procedure) according to equation (1):

equ. 1: $$Q_{aux,y} = (Q_{L,y} / Q_{L,test}) * Q_{aux,test}$$

with
- $Q_{aux,y}$: annual thermal energy load of auxiliary heater[kJ]
- $Q_{L,y}$: annual domestic hot water and space-heating load [kJ]
- $Q_{L,\ test}$: measured domestic hot water and space-heating load during core phase of the test [kJ]
- $Q_{aux,test}$: measured thermal energy load of auxiliary heater during the core phase of the test [kJ]

The annual domestic hot water and space-heating load $Q_{L,y}$ can be calculated according to equation (2) as follows:

equ. 2: $$Q_{L,y} = (365/6) * Q_{L,tap,test} + (N_{dd,y} / N_{dd,test}) * Q_{L,sh,test}$$

with

$Q_{L,tap,test}$: measured domestic hot water load during the core phase of the test [kJ]

$Q_{L,sh,test}$: measured space-heating load during the core phase of the test [kJ]

$N_{dd,y}$: annual number of degree days [K]

$N_{dd,test}$: number of degree days during the core phase of the test [K]

The number of degree days N_{dd} for a specific day is defined as the difference between 18°C and the mean ambient temperature for that day as far as this daily mean temperature is below 15 °C.

5 Results

The fractional energy savings f_{sav} can be used as a comparison criteria for the thermal performance of the different combisystems. This figure shows the percentage of energy that can be saved using a solar combisystem instead of a conventional heating system. The fractional energy savings f_{sav} are calculated according to equation (3).

equ. 3: $$f_{sav} = \frac{Q_{conv} - Q_{aux,y}}{Q_{conv}} \cdot 100\ \%$$

with

equ. 4: $$Q_{conv} = Q_{L,y} + Q_{ls}$$

and

Q_{ls} representing the heat losses of the hot water store of a conventional heating system [kJ].

As meteorological data for the annual performance prediction the weather data file TRY (Test Reference Year) Zürich (climate zone 2 according to IEA SH & C, Task 26) was used. As space-heating load the data of the so-called SFH60 reference house were used with a space-heating load of 8545 kWh per year (in this climate zone).

The comparison of the both test procedures was carried out for the combisystem shown in Figure 1. In order to perform the comparison for "two" systems, different collector areas (7 m^2 and 14 m^2) were used. Table 1 shows the results determined with the ACDC procedure.

Table 1: Results according to the ACDC Test Procedure

	$Q_{L,tap,test}$ [kWh]	$Q_{L,sh,test}$ [kWh]	$Q_{aux,test}$ [kWh]	$N_{dd,test}$ [K]	$N_{dd,y}$ [K]
7 m^2	49,1	130,5	131,1	54,0	3238,6
14 m^2	49,3	130,5	110,9		
Required	49,2	132,8	-	-	-

If the annual domestic hot water and space-heating load $Q_{L,y}$ is calculated as proposed for the ACDC procedure [1] (see equation 2) it comes up to 10830 kWh instead of 11534 kWh (2989 kWh domestic hot water load plus 8545 kWh space-heating load) which is the result of the annual performance prediction. The reason for this discrepancy is not obvious, because the six day core sequence and the number of degree days given in Table 1 for the use in equation 2 are based on the same weather and load data which were used for the annual performance prediction.
However, in order to overcome this problem, instead of calculating $Q_{L,y}$ with the proposed calculation method, the auxiliary energy $Q_{aux,y}$ was directly calculated with the nominal value for $Q_{L,y}$ according to equation (1).
The annual auxiliary energy consumption ($Q_{aux,y}$) and the fractional energy savings (f_{sav}) determined according to both test procedures are shown in Figure 2.

For both collector areas the fractional energy saving resulting from the two procedures differs considerably. This can be explained by the fact of the test sequence used for the ACDC procedure: Due to the extreme reduction of a year to six days, the heat can in some way be ‘seasonally’ stored during the ACDC test sequence. In reality this will not be possible for a system (store) of this size. This effect also explains why the difference of the fractional energy savings (when applying both procedures) becomes still larger with an increasing collector area.

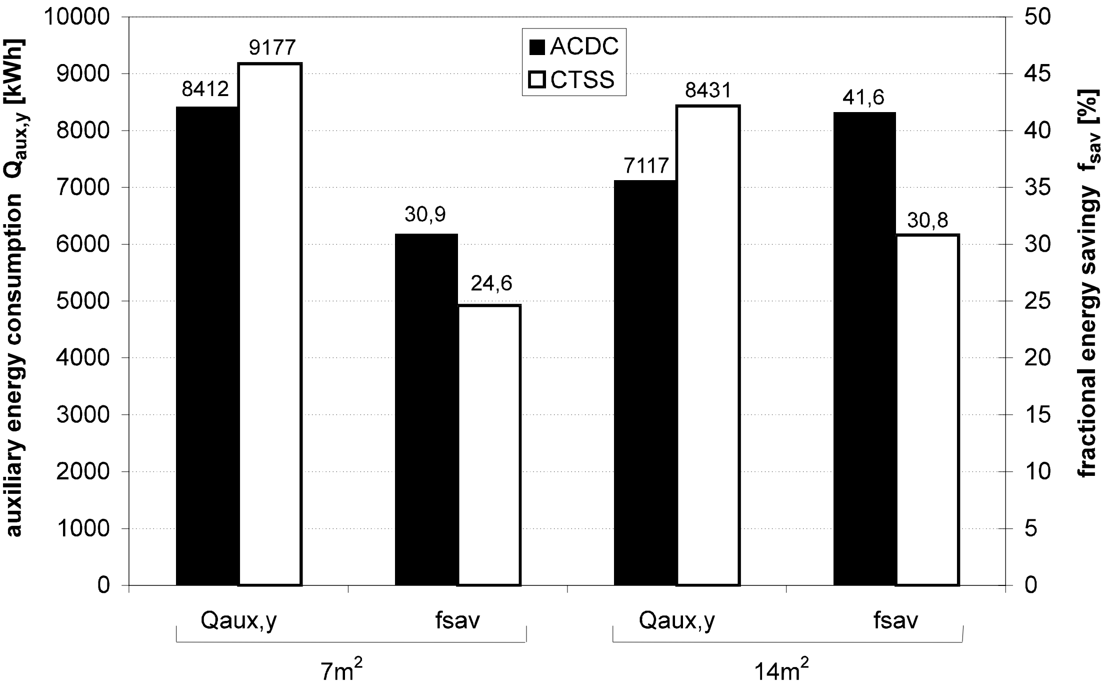

Figure 2: Annual auxiliary energy consumption ($Q_{aux,y}$) and fractional energy savings (f_{sav}) determined according to both test procedures for two different collector areas

6 Conclusions

With the ACDC procedure the real behaviour of a whole combisystem (excluding the collectors) can in principle be described very precisely. An expensive performance test of the combistore and a computer based parameter identification can be omitted. The annual auxiliary energy consumption can be determined by means of simple calculation methods. However, the ACDC procedure also requires the emulation of the collector and therefore a separate collector test in order to determine the collector parameters. One problem of the ACDC procedure is the reduction of a complete year to six days, so that in the test cycle the effect of 'seasonal heat storage' occurs. In principle it should be possible to prevent this by prolonging the test cycle in dependence of the system (store) size.

An other, more fundamental problem is the choice of the days in a way that they represent exactly the average weather conditions for a complete year. Small deviations (and measuring errors) become more and more significant when calculating the heat quantities for a whole year. The thermal condition of the store before and after the 'core phase' (beginning and end of a year) should be identical for a correct calculation. As this will not be the case for most test sequences carried out, it is recommended to introduce a correction factor for the calculation of the auxiliary energy consumption depending on the difference of the internal energy inside the store. However, this leads to the problem that the internal energy of the store directly before the 'core phase' can not be measured precisely without using temperature sensors inside the store. But the use of sensors inside the store is not desired since they might influence the thermal stratification and lead to additional heat losses.

Another disadvantage of the ACDC procedure is that the calculated heat quantities in each case are only valid for the conditions simulated in the respective test sequence (meteorology, load profiles, system parameters). If the parameters are changed (e. g. another load) the complete ACDC test has to be carried out once again.

With the CTSS procedure such a parameter variation can be performed much faster and less expensive, since only a new annual system simulation is required. The CTSS procedure for combisystems has been validated within the ‘Kombianlagenprojekt’ by recording measurement values at an existing combisystem for several years. Here, a maximum relative deviation of 5 % could be determined when comparing the measured and calculated values for the fractional energy savings.

The large differences of the fractional energy savings determined with the two test procedures showed, that the ACDC procedure is not suitable for the comparison of different systems based on annual performance indicators.
The differences in the results obtained by the two procedures for the different collector areas also shows that at present, the DC procedure (direct comparison of various combisystems) cannot be applied to systems of different size. As the ACDC procedure is still under development, the results presented in this report should only be considered as preliminary results. This procedure is presently still being optimised (regarding test sequences and calculation method).

7 References

[1] H. Visser; Direct characterisation test procedure for solar combisystems, Second draft, 18.09.2001, IEA SH & C Task 26 (Solar Combisystems)