IEA SHC TASK 26 "SOLAR COMBISYSTEMS" IS COMPLETED – A FRUITFUL INTERNATIONAL 4-YEARS CO-OPERATION BETWEEN RESEARCHERS AND INDUSTRY WITH A NUMBER OF PRACTICAL RESULTS

J.-M. Suter[1]; T. Letz[2]

1) Suter Consulting, Thunstrasse 115, P.O. Box 130, CH-3000 Bern 16

2) ASDER, 299 rue du Granier, P.O. Box 45, F-73232 St-Alban Leysse Cedex

ABSTRACT

Task 26 of the Solar Heating and Cooling Programme (SHC) of the International Energy Agency (IEA) is completed. For 4 1/2 years 50 researchers and industry participants from 10 countries have co-operated in research and development on the so-called solar combisystems, i.e. the solar heating systems for the combined domestic-hot-water preparation and space heating. The main results are a Design Handbook for planners, architects and engineers, a new characterisation method of solar combisystems, called FSC (fractional solar consumption), and a computer-assisted simple design and performance prediction tool, called Combisun, based on the FSC approach. Task 26 began with an inventory of 21 existing combisystems found on the market in the participating countries, and classified them. Detailed system performance simulations enabled system optimisation and inter-comparison. Experimental studies were carried out about the collector array's transient behaviour when stagnation occurs and collector integration in building façades. Significant progress towards the extension of standardised test procedures for solar water heaters to solar combisystems was encountered. All of these advances are reported in the Handbook, which also gives a number of recommendations on reliability and durability aspects, including 20-years large-scale market experience with drainback collector technology.

RESUME

La Tâche 26 du Programme Chauffage et climatisation solaire de l'AIE vient de s'achever. 50 chercheurs et industriels de 10 pays ont collaboré pendant quatre ans et demi au développement et à l'analyse des installations solaires combinées pour le chauffage et l'eau chaude sanitaire. Les résultats principaux sont un Manuel pour l'étude et le dimensionnement, à l'intention des architectes et des ingénieurs, une nouvelle méthode de caractérisation des installations solaires combinées, baptisée FSC (*fractional solar consumption*) et un outil convivial d'aide à la conception et au dimensionnement de ces installations, nommé Combisun, basé sur la méthode FSC. Un inventaire et une classification des 21 types de systèmes commercialisés dans les pays participants ont été établis. Ces systèmes ont été optimisés et leurs performances comparées à l'aide de simulations détaillées sur ordinateur. Le comportement dynamique des champs de capteurs quand survient une stagnation a été étudié expérimentalement, de même que l'intégration des capteurs en façade. Des pas importants ont été faits en vue de l'extension aux systèmes combinés des procédures normalisées d'essai appliquées actuellement aux chauffe-eau solaires. Le Manuel présente toutes ces nouveautés et contient aussi une série de recommandations en rapport avec la fiabilité et la durabilité, ainsi que l'expérience de 20 années d'utilisation à grande échelle de la technique « drainback ».

INTERNATIONAL CO-OPERATION WITHIN THE IEA SHC TASK 26 "SOLAR COMBISYSTEMS"

Since the beginning of the eighties, the rate of growth in the use of solar collectors for domestic-hot-water preparation has shown that solar heating systems are both mature and technically reliable. But for several years solar thermal systems have seemed to be essentially restricted to this application. Since 1990 and further, the industry offered more and more solar combisystems, but basic scientific knowledge was missing in certain areas and methods. The designs mainly resulted from field experiences and they had not been carefully optimised. A first international survey in 1997 revealed more than 20 different designs that did not necessarily reflect local climate and local practice only. Collaborative work in analysing and optimising combisystems was seen as a proactive action that could favour good systems on a more global market than the national one.

Common definitions of terms were also missing and neither standardised test procedures nor a classification scheme were available for this type of system. This means that it was difficult to determine a meaningful performance rating and even more difficult to compare the systems. The question of finding a "best" solution in a given situation had no answer in 1997. Therefore, international co-operation was needed to analyse and review more designs and ideas than one sole country could cover. It was felt that an IEA activity was the best way to deal with solar combisystems in a scientific and co-ordinated way. From autumn 1998 to December 2002, 35 experts from nine European countries and the USA and 16 solar industries have been working together within Task 26 to further develop and optimise solar combisystems for detached single-family houses, groups of single-family houses and multi-family houses [1]. Furthermore, standardised classification and evaluation processes and design tools were developed for these systems. Proposals for the international standardisation of combisystem test procedures were another major outcome of Task 26. Moreover, Task 26 led to the construction of test facilities for solar combisystems in five European countries.

The further development and optimisation of systems and their designs by the Task 26's participants, on the basis of detailed computer simulations using adequately defined reference conditions, resulted in innovative systems with better performance-cost ratings. Besides, architectural integration of the collector arrays together with durability and reliability of solar combisystems were investigated. This should lead to greater confidence of the end user in this technology.

Solar industry and builders were involved in all activities in order to accelerate dissemination of results as broad as possible. In conjunction with the regular experts' meetings, six well-attended Industry Workshops were organised in the hosting country (each time another one). Three Industry Newsletters were published, to regularly inform solar industry of the Task progress. Finally, six European participating countries plus Italy were involved in a 3-years parallel EU-Altener project aiming at disseminating the Task 26 results (national industry seminars and workshops; more than 200 built examples of solar combisystems, the performance of 33 among them being monitored; presentation sheets, including cost and performance estimation, for all installed systems) [2].

An overview of Task 26 outcomes is available from the IEA SHC web site [3]. To download Task 26 publications, refer to [4]. The main outcomes are a coloured booklet giving an overview of the solar combisystems on the market in the participating countries in the year 2000 [5], a design handbook for architects and engineers [6] and a computer-assisted simple design and performance prediction tool Combisun, available from [2], based on the FSC procedure presented below. Also available are 19 technical reports, the proceedings of the six Industry Workshops and the three Industry Newsletters [3, 4].

HIGHLIGHTS FROM THE DESIGN HANDBOOK [6]

Stagnation behaviour

In summer, solar space heating systems often reach stagnation conditions as in one day with clear sky the storage tank reaches quite early the maximum temperature (e.g., 95 °C). In this case, the controller switches the collector loop pump off. Then, the temperature of the absorber rises rapidly to the stagnation temperature, which is at 180 to 210 °C for selective-coated absorbers of flat-plate collectors. Task 26 experts extensively studied the stagnation behaviour of collector arrays and collector loops. Figure 1 and Figure 2 highlight the results. It has to be emphasised that a good emptying collector does not necessarily implies a trouble-free operation at and after stagnation, as a poor collector array and/or collector loop design may drastically deteriorate the originally good collector emptying behaviour.

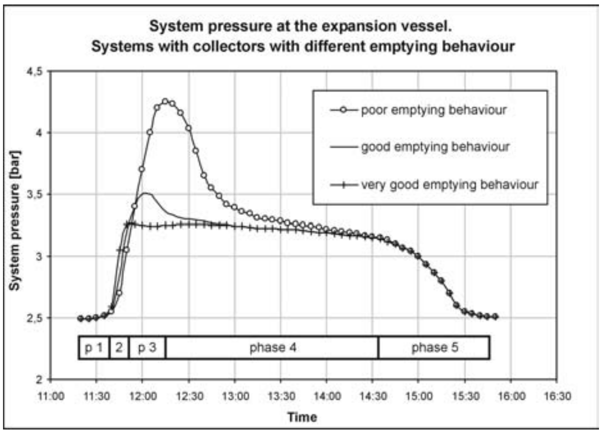


Figure 1: Typical pressure variations in the collector loop at stagnation, in three variants with different collector emptying behaviours. A high-pressure peak indicates a large steam production in the collector; this steam re-condensates at some place in the collector loop, very efficiently transporting thermal energy to the condensing place and exposing the corresponding system component to high temperatures, with possible damage. Five phases are observed: 1) expansion of liquid; 2) liquid pushed out of collector; 3) collector emptied by boiling (shall be avoided!); 4) collector emptied by superheated steam; 5) collector refilled.

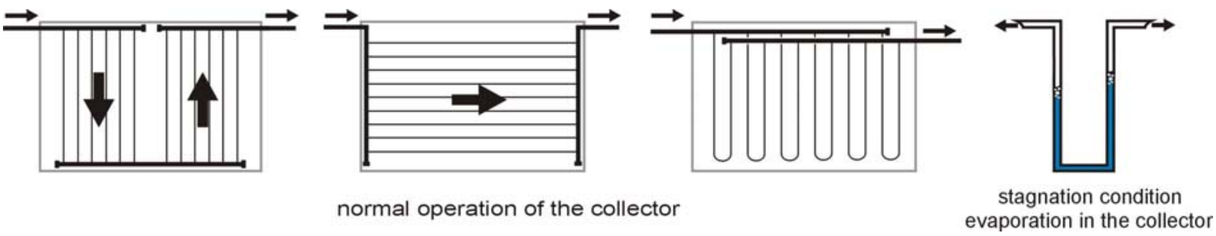


Figure 2: Examples of common collector circuitries with poor emptying behaviour. Left: normal operation; right: steam formation in the collector at stagnation (schematic). For a good emptying behaviour the pipe geometry shall enable the collector contents to be expelled at stagnation simultaneously through both connecting pipes without steam production.

Drainback technology

Drainback technology provides an interesting alternative for overheating protection of fluid in the solar collector loop and also prevents the heat transfer fluid from freezing (Figure 3).

Thanks to drainback of the collector fluid when the collector circuit is not running, the circulation can operate using plain water without (antifreeze) additives. This system concept is based on draining water from the tilted collector and outdoor collector pipes using gravitational force and replacing the liquid with air from the top. Normally, this air is taken from some part of the (closed) collector loop, to prevent from corrosion.

Architectural Integration of Collectors

The growing interest for solar combisystems brings new challenges for architects, building services engineers and the solar industry. The collector area needed for these systems (10 to 30 m^2 for a single-family house) is substantially larger than for solar water heaters. With this size the collector array becomes a dominant architectural element. A perfect aesthetics is required, as well as modular sizes, in order to get a perfect architectural integration. Collectors can be regarded as multifunctional building elements that provide both shelter and heat. Their appearance has to be improved. Absorbers are dark, but no longer necessarily black. As solar collectors involve both technology and architecture, and also demonstrate social and ecological awareness, concerted professional efforts of engineers and architects are needed to make a success of the integration of solar collectors into the building envelope.

Facade-integrated collectors (Figure 4) are less common today than roof-integrated collectors, although they present a number of advantages with regard to energetic performance, building physics and architectural aesthetics. Solar irradiation on a south-facing facade collector has no high value from May to August. Hence, this collector less often runs into stagnation than if it was roof-integrated. Moreover, solar irradiation on the collector is significantly enhanced by reflection on snow, if any. Façade integration of collectors reduces the heat loss from the building and improves the U-value of the collector itself. It is a cost-saving factor, as building components have more than one function. One specific building physics issue has to be considered at design time: water vapour diffusion through collector walls must be possible through the inner wall surface, as the collector is a vapour-tight barrier. Pre-fabricated wall elements including collectors are already available on the market. Facade integration puts an end to the race towards highest possible collector efficiencies, observed in the past decade.

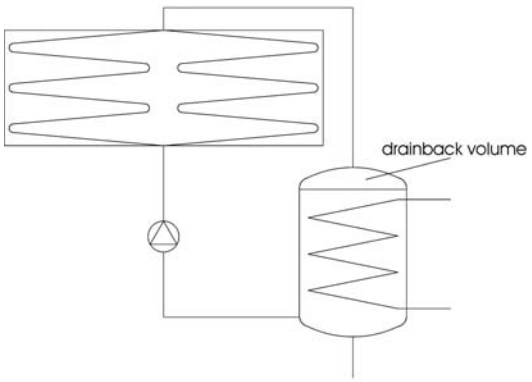


Figure 3 (left): A drainback system from the Netherlands. In this country, drainback technology evolved from regulations in the 1980s for quality of drinkable water. It is still applied in most solar heating systems, due to its advantages (cheaper heat transfer fluid with better heat transfer properties, less maintenance, etc.) compared with the use of antifreeze fluids. Emphasis is put on education and training as special skill is needed for design and installation.

Figure 4 (right): Facade-integrated collectors. Source: Sonnenkraft, Austria

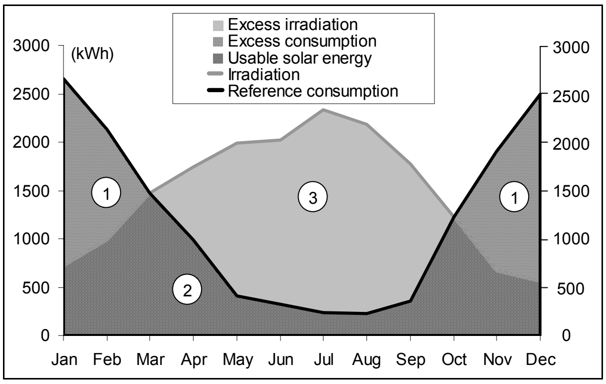
Solar Combisystems Characterisation by means of the FSC Method

A new indicator, called Fractional Solar Consumption (FSC), was introduced: it can be considered as the maximum theoretical fractional energy savings, which could be reached if the solar combisystem had no loss. It is calculated by dividing the yearly "usable solar energy" (② area in Figure 5) by the yearly total reference consumption (①+② area in Figure 5) calculated from the space heating and domestic-hot-water (DHW) loads, the heat losses of a reference DHW tank and the efficiency of a reference auxiliary boiler. The yearly "usable solar energy" is calculated on a monthly basis, considering for each month the smallest value of two, the available solar irradiation on the collector area and the monthly reference consumption. FSC is a dimensionless quantity, which simultaneously takes into account the climate, the building (space heating and domestic-hot-water loads), the collector area and its azimuth and tilt angle, but which does not depend on the choice of any particular solar combisystem.

Figure 6 shows an example of the relationship between the fractional energy savings and FSC, for a French combisystem. It can be seen that the points for various climates and loads are close to a mean parabola. This means that the fractional energy savings can be expressed in terms of FSC by a very simple parabolic equation, and the coefficients for it can be identified with a very good regression coefficient (close to 1).

$$\hat{f}_{sav} = a \,.\, FSC^2 + b \,.\, FSC + c \tag{1}$$

The 3 coefficients a, b and c are the FSC characteristic of the solar combisystem. Analysis of simulations results obtained by Task 26 showed that this approach can be used for both performance indicators considered, the thermal and the extended fractional energy savings. (The first does not take into account the parasitic electricity consumption of the combisystem, the latter does.) The accuracy of the method can even be improved by introducing a storage size correction factor SC, which accounts for the specific storage volume per m² of collector.



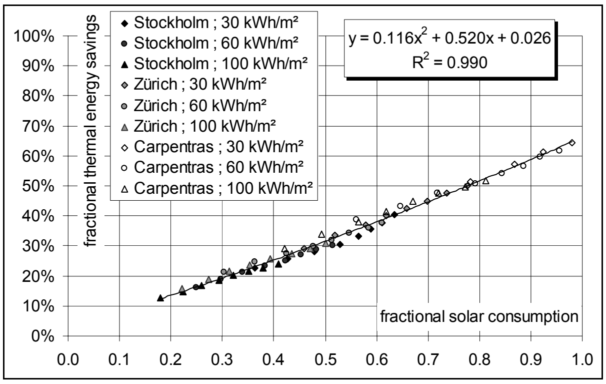
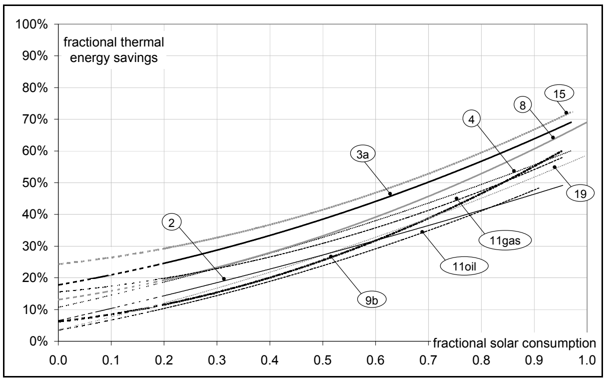


Figure 5 (left): Monthly plot of final energy consumption for a reference system and solar irradiation on a specific collector area of specific azimuth and tilt angle.

Figure 6 (right): Fractional thermal energy savings vs. fractional solar consumption for the combisystem #3a described in [5], calculated with the French design programme PSD-MI.

Nine systems have been simulated in the framework of Task 26. All use the same reference collector. This choice was necessary to be able to compare the system concepts, including hydraulic design and control strategies. Figure 7 gives the results for the fractional thermal energy savings. There is a significant spread in characteristics. However, the slopes are fairly similar for most systems, the major difference being the absolute level. This level is mainly determined by the efficiency of the auxiliary heater and by the store losses, compared to those for the reference system. A similar set of curves was obtained for the extended fractional energy savings (Figure 8). However, these results cannot be used for the direct comparison of the commercial systems built according to the system concepts considered here, as the solar collectors in commercial systems differ from the Task 26 collector.

The f_{sav} vs. FSC diagrams can also be fruitfully used for the presentation of monitoring results, in order to compare combisystems whichever the system concept and the location. The simple computer-assisted design and performance prediction tool Combisun developed within the Altener project [2] is based on the FSC approach.



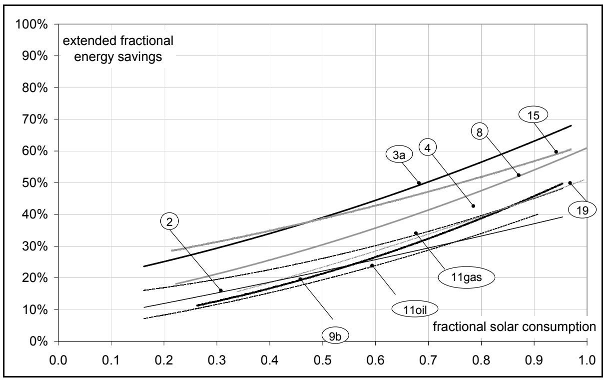


Figure 7 (left): System inter-comparison by means of the fractional thermal energy savings plotted as a function of the fractional solar consumption, for 9 systems simulated in Task 26.

Figure 8 (right): Extended fractional energy savings versus FSC for the same systems.

DISCUSSION

The Design Handbook, the FSC approach and the simple design tool Combisun represent major advances towards a broad market penetration by high-quality, performance and cost-optimised solar combisystems. These systems will reduce CO_2 emissions considerably more than solar water heaters do. In some of the Task 26 countries, their market share is already far from negligible. The systematic scientific study of these systems by Task 26, the results of which are now available for the whole international solar community, will lead on the market to more compact, mostly pre-fabricated units with highly roof or facade-integrated collectors.

ACKNOWLEDGEMENTS

The authors express their gratitude to the Swiss Federal Office of Energy and to the *Agence française de l'environnement et de la maîtrise de l'énergie* (ADEME) for the financial support of their Task 26 participation.

REFERENCES

1. General information on Task 26: http://www.iea-shc.org/task26/introduction.htm
2. Parallel Altener project "Solar Combisystems": http://www.elle-kilde.dk/altener-combi/
3. Overview of Task 26 outcomes: http://www.iea-shc.org/task26/outcomes.htm
4. Task 26 publications for downloading: http://www.iea-shc.org/outputs/task26/index.htm
5. Suter, J.-M; Letz; T., Weiss; W.; Inäbnit, J.: Solar Combisystems in Austria, Denmark, Finland, France, Germany, Sweden, Switzerland, the Netherlands and the USA – Overview 2000. IEA SHC – Task 26, Büro n+1, Bern, Switzerland, ISBN 3-905583-00-3, 2000
6. Weiss, W. (ed.): Solar Heating Systems for Houses – A Design Handbook for Solar Combisystems. James and James, London, to be published