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EXPERIENCES WITH A MOBILE, STAND-ALONE TEST FACILITY FOR SOLAR THERMAL COLLECTORS AND SYSTEMS

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ABSTRACT

Solar thermal technology is a booming market. As a result, a wide range of solar thermal collectors and systems are produced by numerous manufacturers all over the world. In order to assess thermal performance, manufacturing quality, safety of operation and to identify potential for further improvement, accurate testing of solar thermal collectors and thermal solar systems is required. Standardized testing procedures for solar thermal collectors are e.g. specified in the European Standard EN 12975 or the international standard ISO 9806 and for solar thermal systems in the South African Standards SANS 1370 (Mechanical tests) and SANS 6211-1 (Thermal tests) as well as in the international standards ISO 9459-2 (CSTG-method) and ISO 9495-5 (DST-method).
In order to secure a growing market for solar thermal products in South Africa and its neighbouring countries, it is essential to establish a solar thermal test institute as a service provider for manufactures and suppliers in the Southern African area. For this purpose, a turn-key test facility for solar thermal collectors and systems was purchased from the German company Solar- und Wärmetechnik Stuttgart (SWT). SWT is a spin-off company from the Institute for Thermodynamics and Thermal Engineering (ITW) of the University of Stuttgart. ITW has been working in the solar thermal field for more than 30 years and is operating the "Research and Test Centre for Thermal Solar Systems" (TSZ). The TZS is the largest solar test centre in Europe. Hence, very substantial experience related to testing and the construction of test facilities has been gained at ITW and SWT.
The test facility for the South African Bureau of Standards (SABS) is part of a project financed by the Central Energy Fund (CEF) and the United Nations Development Program (UNDP). The facility was manufactured and instrumented by SWT based on a standard office container as a turn-key product. Before the test facility arrived from Germany, two staff members of SABS were trained for one week at SWT in Stuttgart, Germany. An additional training program took place on-site, after the test facility had been set-up and commissioned in Pretoria. The initial operation was performed together with an expert from SWT.
After shipment to South Africa the test facility could be taken into operation within a few days at the South African Bureau of Standards (SABS), located in Pretoria. The South African Bureau of Standards has been working with the mobile, stand-alone test facility since the beginning of 2007 and has already tested several systems according to SANS 6211-1. To-date, the experiences gained with the mobile, stand-alone test facility are very good. It operates without notable problems and delivers reliable and accurate results.

The paper describes the principle set-up of the test facility as well as the experience gained by SABS.

INTRODUCTION

Testing of solar thermal collectors and systems is required in order to asses the thermal performance and the quality of these products. This is especially necessary since solar thermal technology is a booming market and a wide range of solar collectors and systems are produced by numerous manufacturers all over the world.
Well established test procedures for solar collectors are specified in the European Standard EN 12975 or the international standard ISO 9806, and for solar thermal systems in ISO 9459-2 (CSTG-method) and ISO 9459-5 (DST-method).
In order to perform the tests specified in these standards, each test laboratory or manufacturer requires appropriate test facilities. Usually separate test facilities are used for collector and system testing. Typically, these test facilities are individually designed and installed at a specific location.

2. THE TEST FACILITY

The requirements for performance testing of solar collectors and thermal solar systems are different. Therefore, it is common practice to use specifically designed test facilities for testing these two categories of solar thermal products. This results in at least two test facilities, each containing a large number of measuring equipment. Besides the fact that the set-up of the two test facilities requires a very substantial investment it also results in relatively high operational costs for the maintenance of the two facilities and the calibration of all the different sensors.
In order to decrease the number of test facilities and thus to decrease the initial investment and the operational costs an all-in-one test facility was developed by SWT. A further requirement for this facility was some degree of mobility. It is possible to dismantle the whole facility within a couple of hours, load and ship it to any place and set it up again within a short time. This mobility also offers the advantage that the facility can be delivered as a ready to use turn-key product to the customer and put in operation within one day. Furthermore, the test facility is designed in such a way that it can be operated independent from a fresh water or cooling water net. Most importantly, the test facility conforms to standards ISO 9459-2 and ISO 9459-5 for system tests, and to the standard 12975-2 or ISO 9806 for solar collectors.

2.1 System tests according to ISO 9459-2 and ISO 9459-5

In part two and five of the standard series ISO 9459, two possibilities for performance testing of domestic solar thermal hot water systems are described.
With the CSTG (Complete System Testing Group) test method standardized in ISO 9495-2, only solar thermal systems without an integrated auxiliary heating element can be tested. The CSTG method focuses only on sums of energy. For the determination of the performance of a solar hot water system according to the CSTG method, the solar irradiance during the test day is summed up. In a second step, the useful energy withdrawn from the system at the end of the day is calculated based on measurements of inlet and outlet temperatures and flow rate. Finally the withdrawn daily energy is divided by the daily solar irradiance. This test is performed for several days with different irradiance values. Based on the results obtained in this way the annual system performance can be calculated for specific reference conditions.
During the test of the system according to the DST-method (Dynamic System Test).standardized in ISO 9495-5 the system is operated for a few days according to specified test conditions. From the measured data recorded during this short-term test, specific system parameters are determined by means of parameter identification. Based on these parameters the thermal performance of the thermal solar system can be determined for specified reference conditions by means of annual system simulations.

2.2 Collector tests according to ISO 9806 / EN 12975

In order to determine the efficiency parameters of solar thermal collectors according to ISO 9806 or EN 12975, two different procedures can be used: the steady state method and the quasi dynamic test method.
During the steady state test, all boundary conditions such as solar radiance and ambient temperature must be constant. After recording data points over a representative range of operating conditions, the collector efficiency curve can be determined.
During the quasi dynamic test the boundary conditions must vary. Based on a series of measurements, specific collector parameters are determined, as well. With the quasi dynamic test method, additional parameters such as the heat capacity of the collector and the incident angle modifier coefficient can be determined in addition to the efficiency curve.

2.3 Set up of the test facility

One aim of the newly developed test facility is to combine all three test methods in a single test facility. This test facility must be able to fulfil all requirements and qualifications resulting from the above mentioned standards.
The housing of the test facility is a conventional 20 foot office container. In this container the hydraulic of the temperature unit is located as well as the measuring equipment and the data logging instruments. In order to operate the facility independent from a cooling network, a chiller combined with a 600 litre cold water store is installed. With the exception of the chiller, all components are located inside the container. Fig.1 shows the schematic layout of the major components.

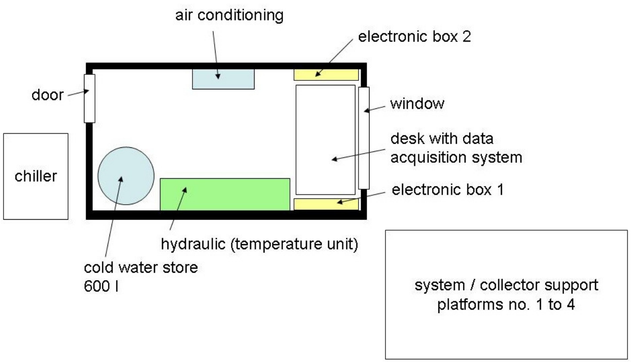

Fig. 1: Arrangement of major components (bird's view)

The facility is designed in such a way that it allows for parallel testing of

- 4 collectors (according to EN 12975 / ISO 9806) or
- 4 systems according to ISO 9495-2 (CSTG-method) or
- 2 systems according to ISO 9495-5 (DST-method)

To realise these different test configurations, the hydraulic arrangement consists of one main loop that can be divided into six smaller loops by using several valves. These six loops are required for testing two solar thermal systems according to the DST-method at the same time. The hydraulics for testing according to ISO 9459-2 and ISO 9806 / EN 12975 consist of only one hydraulic loop, which can be used to test four systems (CSTG-method) or four collectors simultaneously. In Figure 2, the layout of the complete hydraulic arrangement is shown.

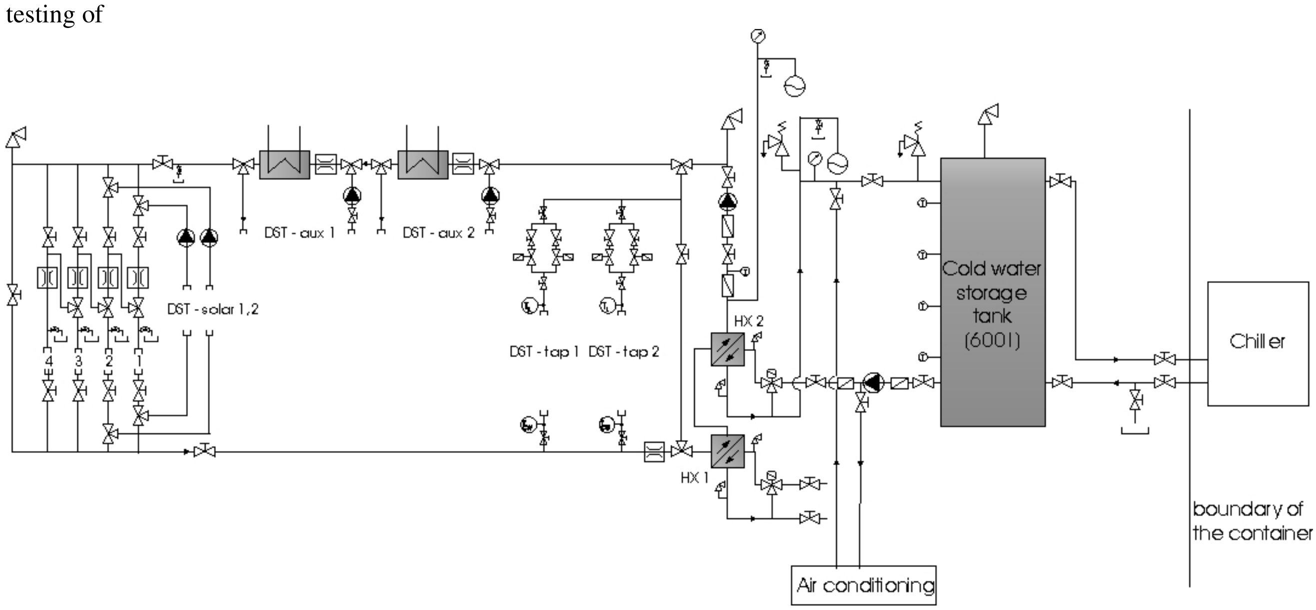

Fig. 2: Circuit diagram of the complete hydraulic arrangement

On the left side in the diagram the four connections for testing the systems (ISO 9459-2, CSTG-method) or for the collectors (EN 12975) are located (1-4). For the DST-method (ISO 9459-5), connections for two collectors (1-2) including the two necessary connections to the solar collector loop (DST-solar 1-2) are depicted. The middle part of the hydraulic circuit is solely related to the DST-method, since there are the connections for the thermal auxiliary heating loops (DST-aux 1-2) and the storage tanks (DST-tap 1-2). The first heat exchanger (HX1) in flow direction offers the possibility to connect an optional external cooling net. If this is not available, the heat will be removed via the second heat exchanger (HX2), which is on the secondary side connected to the cold water store. The cooling circuit also supplies the air conditioning unit inside the container with cold water. On the right hand side of the vertical line, which symbolizes the wall of the container, the chiller is located.

Fig. 3: Chiller connected to the container test facility

This chiller is positioned outside the container because this allows a better supply of fresh air to the refrigerant condenser and reduces the noise level inside the container. Figure 3 shows the chiller connected to the container test facility.
All hydraulically connections to the equipment being tested are located outside the container and are realized with conventional

1 inch screw fittings, countersunk into the container walls. In Figure 4 the connections to the collectors and systems being tested are shown.

Fig. 4: Hydraulic connections to systems and collectors

2.4 Durability and reliability testing

In addition to the equipment required for thermal performance testing, the test facility is delivered with the complete equipment required for durability and reliability testing of solar thermal collectors according to EN 12975-2. This comprises test facilities for outdoor exposure, external and internal thermal shock, rain penetration, mechanical load test and internal pressure test.
As an example for the additional capability, the rain penetration test facility is shown in Figure 5.

Fig. 5: The rain penetration test.

2.5 Patent

The mobile, stand-alone solar thermal test facility has been registered for patenting under the number AZ 102007018251.3 at the German Patent Office. Major issues of this patent are the mobile and stand-alone characteristics of the test facility combined with the possibility to perform tests according to three different standards with one single test facility.

3. EXPERIENCE GAINED TO-DATE

Up to now (March 2008) three mobile test facilities have been completed. One of the facilities was sold to the South African Bureau of Standards (SABS) located in Pretoria, South Africa. This test facility is shown in Figure 6.

Fig. 6: The mobile, stand-alone test facility

This test facility is the key component of a solar thermal test centre that was established, co-financed by the United Nations Development Program (UNDP), at the South African Bureau of Standards (SABS). This test facility allows for testing of solar collectors and thermal solar systems according to the CSTG method.
The South African Bureau of Standards is working with the mobile, stand-alone test facility since the beginning of 2007 and has already tested several systems according to ISO 9459-2 (CSTG-method). Before shipping the test facility to South Africa, two staff members of SABS were trained for one week at SWT in Stuttgart, Germany. An additional training programme took place on-site, after the test facility had been set-up and commissioned in Pretoria.
The experiences gained with the mobile, stand-alone test facility so far is very good. The initial operation was performed together with an expert from SWT; it took only a very short time period due to the user-friendly set-up and the detailed instructions supplied with the test facility. The facility was prepared for transport from Germany in such a way that only the wiring to the sensors outside of the container had to be redone in South Africa. Up to now, the test facility operates without notable problems and delivers reliable and accurate results.
Due to the installation of the above mentioned test facility the SABS is able to carry out thermal performance tests and durability tests of solar thermal systems and collectors according to the relevant standards. This is the basis for the formal accreditation of the test laboratory according to ISO 17025
The test facility located at SABS opens substantial market opportunities for South African as well as for the whole Southern African market. Local manufactures are now able to have their products tested by a local test laboratory. As already learned form experience gained in several other countries the cooperation between manufacturers, testing laboratories and research institutions is usually very fruitful. The development of new products and product upgrades will be much faster and forms an excellent basis for a continuously growing solar thermal market.
Furthermore, quality and performance criteria for solar thermal products being sold on the South African solar thermal market can be defined and supervised by a local test laboratory. Especially for a new market it is important to convince the consum-

ers with high quality products. Otherwise, the market will hardly reach a sustained growth.
Up to now several solar thermal systems were tested by SABS. The experiences with testing solar thermal products are still growing and it is assumed that in the near future the tests related to thermal performance as well as reliability and durability can be carried out independently and with reliable and accurate results.

4. CONCLUSIONS AND FURTHER PERSPECTIVES

The development and the set-up of a mobile, stand-alone test facility based on a 20 foot office container were described and the experience gained so far was reported.
For the future it is intended to develop an advanced mobile, stand-alone solar thermal test facility which, additionally, allows for testing of hot water stores according to ENV 12977-3. Furthermore, it is intended to deliver turn-key test facilities to several other test institutes, manufacturers and universities.

With the solar test centre installed at SABS an institution for determining and supervising the performance and quality of solar thermal products in South Africa and in the southern African region was established. The familiarisation phase of the SABS staff has almost reached its end and the best boundary conditions exist for the implementation of SABS as a well established laboratory for reliable testing of solar thermal systems and components. This provides and excellent basis for a well developing solar thermal market in the southern African region.

5. REFERENCES

The European Standards (EN and ENV) and the International Standards (ISO) mentioned above are available from:
www.beuth.de, or
www.cen.eu/cenorm/standards_drafts/index.asp
The South African standards mentioned above are available from the SABS:
www.sabs.co.za