Complete Test Facility For Solar Thermal Collectors And Systems

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Abstract

As a consequence of the booming solar thermal market, a considerable number of new solar thermal products, such as solar thermal collectors or complete systems, is entering the market. For determination of the thermal performance and to certify the durability and reliability of these solar products, testing according to international standards is an important requirement.

To ensure comparable and representative results, tests of solar thermal products are carried out according to well established procedures. Such test procedures are specified e.g. in the European Standard EN 12975 or the International Standard ISO 9806 for solar thermal collectors and in the ISO 9459 for solar thermal systems.

In order to perform the tests according to the above-mentioned standards, test laboratories and manufacturers require appropriate test facilities. Depending on the type of test, separate test facilities are used. These test facilities most often differ significantly, depending on the components to be tested. As a consequence for test laboratories and manufactures, the number of test facilities increases if different products, such as solar thermal collectors and complete factory made solar domestic hot water systems, shall be tested. The growing number of individual test facilities results in high investment costs and leads to significant operational costs, e.g. for maintenance and calibration of sensors.

One possibility to overcome these problems and to reduce the number of different test facilities is to combine identical functions that are required for testing different products into only one test unit.

For determination of the thermal performance of either a complete solar thermal system or only the solar collector, two different test facilities are typically used. Taking into account the two different ways to determine the thermal performance of a solar domestic hot water system (so-called CSTG[1]-method and DST[2]-method) even three different test facilities may be required. To minimize the amount of hardware and the required capital and operational costs, a so-called three-in-one test facility was developed by SWT-Technologie, Germany.

This mobile, stand-alone solar thermal collector and system test facility (see figure 1) is a complete test facility for the determination of the thermal performance of systems according to standards ISO 9459-2 or ISO 9459-5 or the thermal performance of collectors according to standards EN 12975 or ISO 9806. Due to the three-in-one approach, substantial investment

[1] The CSTG –method was originally developed within a European Project by the "Complete System Testing Group" (CSTG). Today this method is standardised in ISO 9459-2

[2] DST: Dynamic System Test. The DST-method is standardised in ISO 9459-5.

costs for construction and maintenance of three different solar test facilities can be saved by the test laboratory.
In addition to thermal performance testing, durability and reliability tests are required e.g. for Solar Keymark certification. In order to perform e.g. internal and external thermal shock tests, rain penetration tests, exposure tests or mechanical impact tests specific multifunctional test facilities were developed.

Keywords: solar thermal collector, solar thermal systems, testing, test facility

1. 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 all-in-one 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 maintenance of the two facilities and 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 the requirements of the standards ISO 9459-2 and ISO 9459-5 for system tests, and to the standards 12975-2 or ISO 9806 respectively for solar collectors. This offers significant advantages concerning the accreditation of the test facility.

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* standardised in ISO 9495-2, only solar thermal systems without an integrated auxiliary heating device can be tested. The

performance determination according to the CSTG method focuses only on sums of energy. For performance testing of solar hot water systems according to the CSTG method, the solar irradiance during each 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 the fluid inlet and outlet temperatures and the 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)* standardised in ISO 9495-5 the system is operated for several days according to well specified test conditions. From the 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 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 respectively, two different procedures can be used: the steady state test method and the quasi dynamic test method.
During the *steady state test*, all boundary conditions such as solar radiance, ambient temperature and collector inlet temperature shall be constant. After recording data points over a representative range of operating conditions, the collector efficiency curve can be determined by means of multi-linear regression using the least square method.
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 all-in-one 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 feet office container. In this container the hydraulics of the temperature unit as well as the measuring equipment and the data logging instruments are located. 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.
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 1, the layout of the complete hydraulic arrangement is shown.

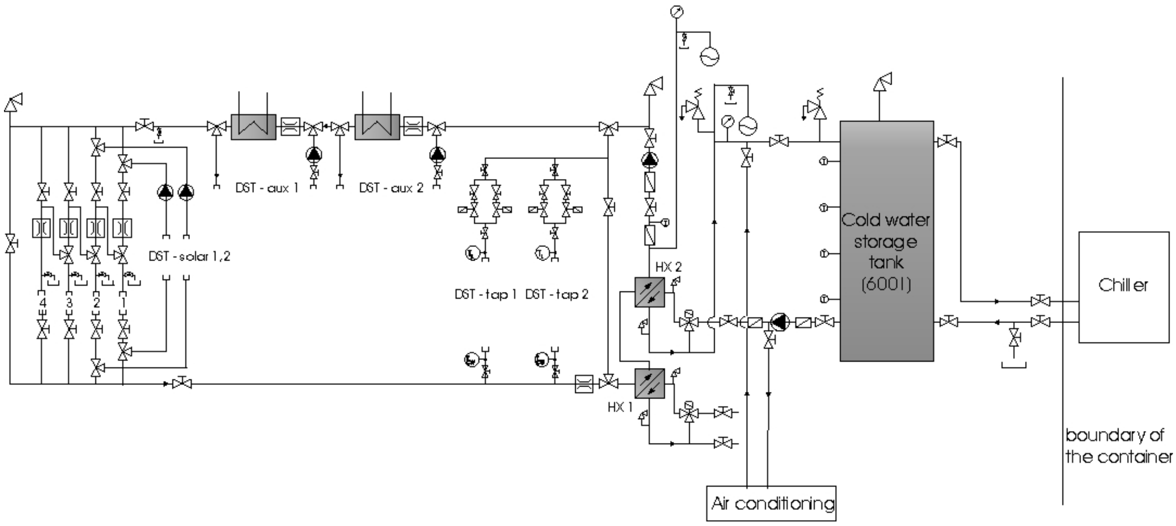

Fig. 1: Circuit diagram of the complete hydraulic arrangement

On the left side of the diagram the four connections for testing the systems (ISO 9459-2, CSTG-method) or 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) of the two systems to be tested. 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 storage tank of the test facility. The cooling circuit also supplies the air conditioning unit inside the container test facility with cold water. On the right hand side of the vertical line, which symbolizes the wall of the container, the chiller is located.

Fig. 2: Chiller connected to the container of the 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 test facility. Figure 2 shows the chiller connected to the container of the test facility.

All hydraulic 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.

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.

Fig. 3: Test facility for outdoor durability and reliability testing (here used for rain penetration test)

Like for thermal performance testing, it is also possible to combine test facilities required for several durability and reliability tests into a single test facility. Figure 3 shows the test facility for the rain penetration test which can also be used for performing external thermal shock tests. For carrying out exposure tests, high-temperature resistance tests and internal thermal shock tests, the same test facility can be used since only the frame with the spray nozzles has to be moved sideward.

Furthermore, the collector test procedures related to the positive and negative mechanical load test, the internal pressure test, and the impact resistance test can be performed using only one single test facility. For this purpose, the collector is mounted on the mechanical load test facility; see figure 4.

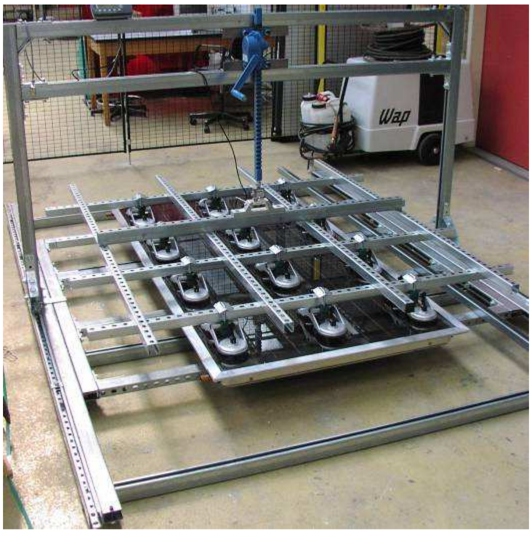

Fig. 4: The mechanical load test facility

Obviously, the mechanical load tests (negative and positive pressure) may be performed subsequently.

After connecting the equipment for the internal pressure test of the collector, the corresponding test can be performed on the mounted collector without any changes on the test facility.

According to EN 12975-2 two methods for performing the impact resistance test are specified. One method is using a steel ball and the other one ice balls.

For performing the impact resistance test by means of a steel ball, the collector does not need to be remounted since the collector is already mounted stiffly enough on the test facility. The supporting frame of the mechanical load test facility is designed as a push loading drawer. Due to this it is possible to pull out the support frame including the mounted collector from underneath the frame simulating the mechanical load.

Fig. 5: Equipment ("ice ball gun") for carrying out impact resistance tests on solar collectors

For performing the impact resistance test with ice balls, it becomes necessary to utilize a completely different test facility. Since the ice balls must have a certain speed at the time of the impact on the collector cover the application of a certain kind of acceleration mechanism ("ice ball gun") is essential. Such an acceleration mechanism is shown in figure 5. Performing an impact resistance test according to this method makes it necessary to mount the collector vertically.

2.5 Intellectual Property

The mobile, stand-alone solar thermal test facility has been registered by SWT 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. Experiences gained to-date

Up to now (December 2008) three mobile test facilities have been completed. The test facilities were delivered by SWT as complete, ready to use turn-key products. One of the facilities was sold to the South African Bureau of Standards (SABS) located in Pretoria, South Africa. The test facility, which is shown in figure 6, allows for testing of solar collectors and thermal solar systems according to the CSTG-method (ISO 9495-2). It is the key component of a solar thermal test centre that was established at the South African Bureau of Standards (SABS) with financial contributions from the United Nations Development Program (UNDP).
Due to the installation of the above mentioned test facility the SABS is now able to carry out thermal performance tests and durability tests of solar thermal systems and collectors according to the relevant standards. This is one important basis for the formal accreditation of the test laboratory according to ISO 17025.
Another test facility which allows testing of solar collectors according to EN 12975-2 and solar thermal systems according to EN 12976 or ISO 9459-2 and ISO 9459-5 respectively is installed at the Research and Test Centre for Thermal Solar Systems (TZS) at the Institute for Thermodynamics and Thermal Engineering (ITW) at the University of Stuttgart.
A further all-in-one test facility was delivered to the Hydrometeorological Service located in Skopje, Republic of Macedonia, where if forms the basis for a solar thermal test and competence centre (see Figure 7).
At present a fourth mobile stand-alone test facility for a Chinese manufacturer of solar thermal products is under construction. This test facility is designed for testing of solar collectors according to EN 12975 / ISO 9806 and for solar thermal systems according to the CSTG (ISO 9459-2) and DST (ISO 9459-5) methods.

Fig. 6: Mobile, stand-alone test facility at SABS, South Africa

Fig. 7: Mobile, stand-alone test facility at Skopje, Republic of Macedonia

4. Conclusions and further perspectives

The development and set-up of a mobile, stand-alone test facility for solar thermal collectors and systems based on a 20 feet office container as well as the test facilities required for durability and reliability testing were described. The quality assurance capabilities of these test facilities are essential for establishing sound market introduction programmes in countries which want to increase their share of renewable energies and safe on the consumption of fossil fuels.

For the future it is intended to extend the mobile, stand-alone solar thermal test facility in such a way that it additionally allows for testing of hot water stores according to EN 12977-3. Furthermore, it is intended to deliver turn-key test facilities to several other test institutes, manufacturers and universities.

References:

EN 12975-1:2006: Thermal solar systems and components - Solar collectors - Part 1: General requirements

EN 12975-2:2006: Thermal solar systems and components - Solar collectors - Part 2: Test methods

ISO 9806-1:1994: Test methods for solar collectors - Part 1: Thermal performance of glazed liquid heating collectors including pressure drop

ISO 9806-2:1995: Test methods for solar collectors - Part 2: Qualification test procedures

ISO 9459-2:1995: Solar heating – Domestic water heating systems – Part 2: Outdoor test methods for system performance characterization and yearly performance prediction of solar-only systems

ISO 9459-5:2007: Solar heating – Domestic water heating systems – Part 5: System performance characterization by means of whole system test and computer simulation

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