Advanced Testing and Quality Assurance Methods for Solar Thermal Systems and Components

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Abstract

Reducing costs and increasing efficiency is important for solar thermal test laboratories. However, this aspect is in contrast to the requirements for high quality and reproducible tests. To overcome this problem the present publication shows methods and procedures in combination with an "all-in-one test facility" to provide both, high quality and reproducible test results within shortest time requiring as less human resources as possible. Furthermore, the reliability of the test methods in combination with the described test facilities is shown by means of .validation measurements.

Keywords: solar thermal, test facility, performance testing, durability and reliability testing, quality assurance, test procedures, standards, certification

1. Introduction

Testing of solar thermal systems and components is mandatory for quality assurance. Furthermore, detailed tests and reproducible test methods ensure the conformity of related products with requirements of certification schemes.

Most certification schemes such as Solar Keymark in Europe, SRCC in the US, Golden Sun in China and SHAMCI in the Arab region require several tests, both for durability and reliability as well as tests for the thermal performance of the related products. To perform all required tests in an accurate and reproducible way, appropriated test facilities are needed by the testing laboratories. These test facilities usually absorb both, a high financial investment and huge amounts of man power to operate the test facilities. To overcome this problem an all-in-one test facility for solar thermal collectors, stores and systems was developed a few years ago. As the regulations and standards have now changed, the "all-in-one test facility" was redesigned, further developed and improved to fulfill the latest state of the art technology for testing solar thermal products.

2. Durability and reliability testing

For testing the performance, reliability, durability and safety solar thermal collectors according to the standard ISO 9806:2017 several tests and therefore various test facilities are necessary.

Besides the test for the determination of the thermal performance the most complex test procedures related to durability and reliability are the following six tests:

- the high-temperature resistance test,
- the determination of the standard stagnation temperature,
- the exposure and pre-exposure test,
- the external and internal thermal shock test,
- the rain penetration test.

Beside these tests the following, minor challenging tests are required:

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- Internal pressure tests of fluid channels,
- Freeze resistance test
- Mechanical load test with positive and negative pressure
- Impact resistance test

Usually, for each of those test procedures a single test facility is required comprising a test stand and measuring equipment. Furthermore, for the operation of the test facility qualified test engineers are necessary.
For example, the **exposure test** requires a test stand for the solar thermal collector, a data logger, temperature sensors and a pyranometer. The **external thermal shock test** requires also temperature sensors, a data logger and a flow rate measuring device. A smart combination of the different test facilities and a clever arrangement of the order the tests are performed reduces not only the measuring equipment and the number of test facilities itself, but also the personal's workload. Furthermore, the time required for testing can be reduced remarkable

E.g. on a sunny day during that the exposure test is carried out, also the external thermal shock test can be performed. Using such kinds of synergy effects requires that the facility for the exposure test additionally fulfills the requirements of the external thermal shock test. In this case, several tests of the test sample can be performed without remarkable additional effort.
If the rain penetration is also performed directly after the exposure test and on the same test facility, the measuring equipment such as the flow rate measuring equipment can be used twice as well.

To reduce the required financial effort and the human resources six test procedures of the above mentioned standard have been combined into one single test facility. So the smart combination of the individual tests related to the test sequence but also related to the test facility itself allows for an effective use of resources.

The above mentioned tests have to be performed consecutive but the test sample can be mounted during the entire test sequence on the same test facility. Even for the external and internal thermal shock test as well as for the rain penetration tests it is not necessary to install the collector to be tested on a different test facility. Fig 1 shows a schematic of the test facility during the exposure test (left) and the rain penetration test (right).

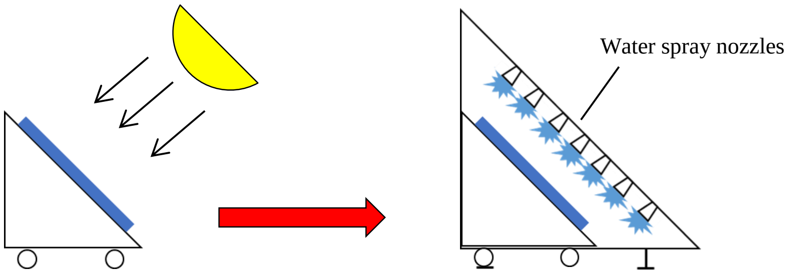

Fig. 1: Test facility for combining the exposure test facility (left) and the rain penetration test facility (right); for performing the rain penetration test the exposure test facility is removed under the water spray nozzles for the rain penetration test facility – or vice versa

For situations and countries where water shall not be drained after spraying it on the collector, a new rain penetration test facility with water recycling was designed. After spraying onto the collector, the water is collected and flows via a channel into a bucket. From there a pump transports the collected water into a store. A second pump transports the water from the store again through the spray nozzles onto the collector. Self-evident, the inclination angle of this test facility is variable and can be adjusted infinitely. Fig. 2 shows a rendering of the new designed rain penetration test facility. A mounted splash guard avoids the waste of water.

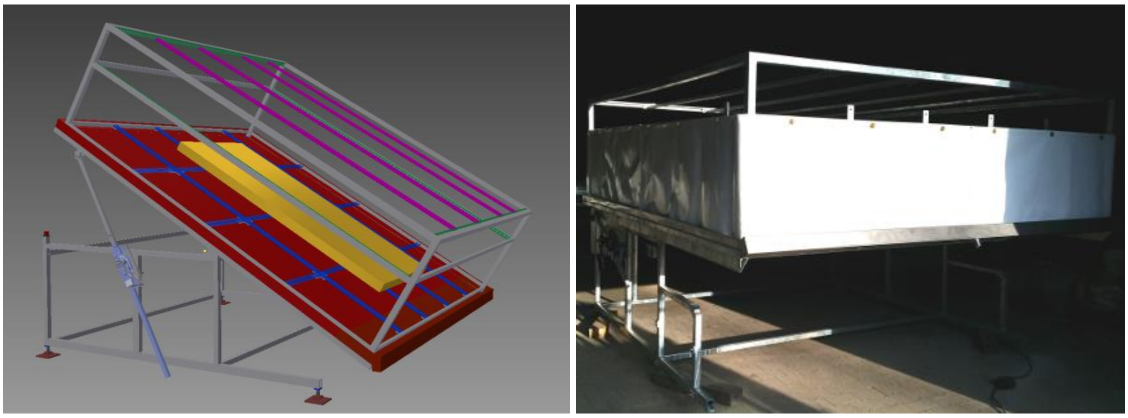

Fig. 2: Rendering (left) and picture (right) of the newly developed rain penetration test facility, which allows water recycling

3. Thermal performance testing of solar thermal systems and solar collectors

The combination of test procedures for testing the thermal performance of solar domestic hot water systems according to ISO 9459-2 and -5 together with the one of solar collectors according to EN 12975 have been already published (Bestenlehner). Due to the replacement of the EN 12975-2 by ISO 9806 some minor changes related to the hydraulics and the measuring equipment have been realized.

However, the test rig for thermal performance testing has been revised significantly to allow a more flexible and multifunctional use. The inclination angel is now adjustable to every desired angle between 0° (horizontal) and 90° (vertical). On the one hand, adjusted to the horizontal, it allows for an easy installation of the test sample. On the other hand, façade collectors intended to be mounted vertically can be tested as well. Additionally the horizontal position of the test rig allows even for testing of solar thermal systems equipped with a self-supporting frame such as e.g. non-pressurized thermosiphon systems mainly produced in Asia. Fig 3 shows renderings and Fig. 4 a picture of the newly designed test rig for performing thermal performance test of solar thermal systems and collectors.

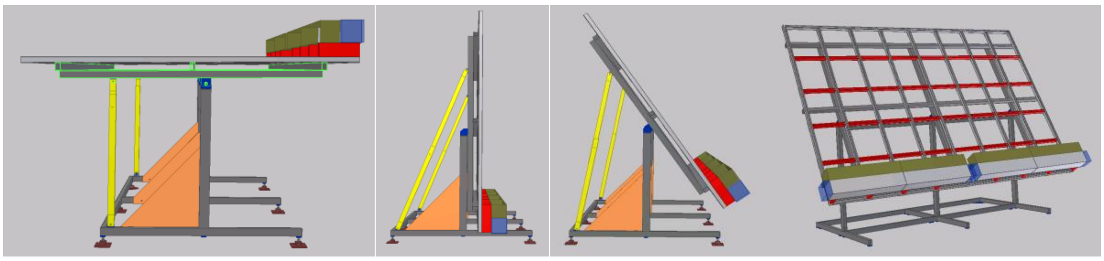

Fig. 3: Renderings of the newly designed test rig for thermal performance tests of solar thermal systems and collectors

Fig. 4: Picture of the newly designed test rig for thermal performance tests of solar thermal systems and collectors

4. Thermal performance testing of thermal energy stores

A third issue for the update of the test facility was the aim to combine the capability of performing tests according to four different test procedures in one test facility in order to determine also the thermal performance of hot water stores using the same test facility. With regard to hot water stores, the test methods of the following standards have been implemented: EN 12977-3, -4, EN 12897, EN 15332. Whereas the test methods defined in the EN 12977 part 3 and 4 are detailed procedures to determine the characteristics of hot water stores and combistores, the test methods described in EN 12897 and EN 15332 are procedures to determine predominantly the heat losses of the store.

Since it is not everywhere possible to install such an all-in-one test facility for testing up to 4 solar thermal collectors, systems and hot water stores in parallel, a small and handy test facility was developed. This test facility is designed for performing tests for the determination of the heat losses of hot water stores according to the above-mentioned standards. Fig. 5 shows a picture of such a test facility.

Fig. 5: Picture of the handy and mobile test facility for the determination of the heat loss rate of hot water stores

5. Validation measurements

To ensure the reliable and reproducible operation of the updated “all-in-one” test facility, validation measurements concerning thermal performance testing have been performed successfully. Exemplarily, the results of the validation measurement of a solar thermal system are presented and discussed in the following. The system under investigation was a thermosiphon system with 1.98 m² solar collector area and a hot water store with 180 L and a jacket heat exchanger. Fig 6 shows the solar thermal fraction of the related solar thermal system at different locations calculated on the basis of the determined test results. The hot water load plotted as tapped hot water volume is varied between 80 L/d and 600 L/d. The results show a decreasing solar thermal fraction with increasing daily load volume, which is quite obvious. The deviation was calculated between the reference measurements and the measurements performed with the updated test facility. All measurements have been performed using the same test samples or solar thermal system respectively. The deviation in the solar fraction is for all measurements below ±2 % (relative).

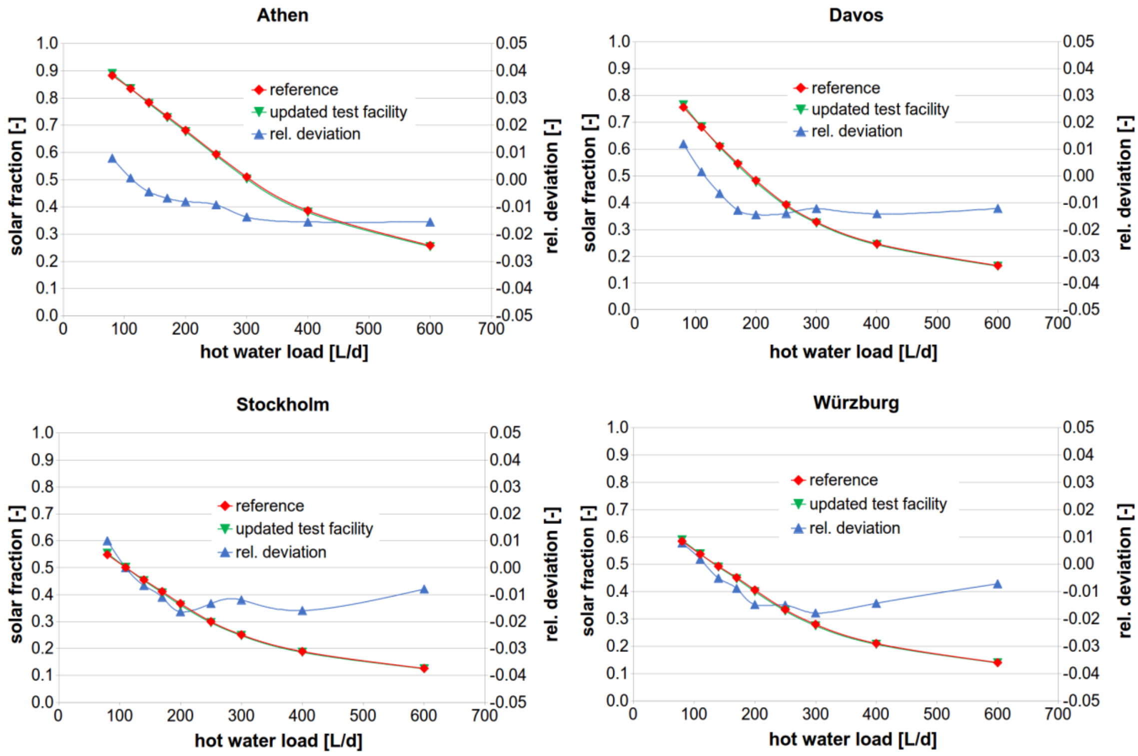

Fig. 6: Presentation of the validation measurements; solar fraction (left ordinate) and deviation (right ordinate) between tests performed with the original and the updated test facility versus tapped hot water volume

6. Summry

The results of the evaluated solar thermal system show that the updated all-in-one test facility enables reliable and cost effective testing. The relative deviation of 2 % of the test results referring to the solar fraction is far below the required limits. The mandatory tests according to the new international standard ISO 9806:2017 the high-temperature resistance test, the determination of the standard stagnation temperature, the exposure and pre-exposure test, the external and internal thermal shock test, and the rain penetration test can be reliable and cost-effective performed with the updated all-in-one test facility.

7. References

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