Quality Assurance in Solar Heating and Cooling Technology

UNDERSTANDING AND USING COLLECTOR TEST STANDARD EN 12975

QAiST
Quality Assurance in Solar Heating and Cooling Technology

CONTENTS

SUMMARY

This brochure gives an overview of the European test standard for solar thermal collectors EN 12975 (hereafter referred to as "the standard"). It aims at promoting the understanding about the standard and its requirements. Therefore this publication will provide a brief overview of the standard to non-technical experts, coming, for instance, from the industry or from public authorities. This brochure will provide a short and simple explanation about how the standard is used for type and performance testing, as well as for innovation and development support.

At the website of the QAiST project[1] you can download this brochure (PDF Format), as well as the complete guide to the standard. The guide was developed in parallel to this brochure and contains more detailed information on most topics, being more suited for technical experts. From now on the guide will be referred to as "the guide".

Please note that the only official document in this context is the standard itself. For up-to-date detailed information always refer to the latest version of the full standard. A revised version of the standard is expected during 2012/13.

Performance testing can be done indoors as well as outdoors and comparison tests show very good agreement for conventional collector designs

[1] www.qaist.eu

STANDARDIZATION – REQUIREMENTS AND BENEFITS

Standardized tests

Standardized tests form the basis for certification according to Solar Keymark[2] and Solar Rating and Certification Corporation[3] (SRCC)

Certification procedures under the European Solar Keymark and the American SRCC are quite different from one another. Solar Keymark certificates are issued by several certification bodies (CBs) while tests are performed by testing laboratories ("test labs") and test results sent to the relevant CB. The test labs must have received ISO/IEC 17025 accreditation to perform tests in accordance with the EN 12975 standard. The CBs, in turn, must be located in Europe and have received ISO/IEC 17020 accreditation. The testing laboratories may be recognized by one or more CBs.

With regard to SRCC certification, only the SRCC can issue certificates. Tests are performed by several recognized testing laboratories. The test labs must be ISO/IEC 17025 accredited to perform tests according to ISO 9806 and US standard 100 and/or standard 600.

Random selection of test samples

Solar thermal test collectors being submitted for testing should be selected randomly by the test laboratory or certification body designated representatives. Please refer to documents on procedures of solar thermal quality management and application forms at the Solar Keymark and the SRCC websites. See also point 3.1 in the guide regarding the required number of collectors to choose from.

According to Keymark scheme rules, performance tests must be carried out for the smallest as well as the largest collector in a family. Therefore, at least three collectors (the smallest for performance tests and two of the largest collector for parallel performance and reliability testing) will be selected at the factory or from stock. It would be sensible to choose some extra collectors and leave them at the factory, if something should happen during transportation or at the laboratory. Measurements of length, width and height of all other collector sizes in the collector family should also be taken *in situ*.

Requirements on Re-testing are minimized

Changes in design, components or materials used in a collector are often a result of product development. If the collector is certified, e.g. with the Solar Keymark, the modification must be assessed by the certification body before it is incorporated in a new product. Depending on the type of changes the manufacturer plans to undertake, the certification body can either approve the changes without any need for re-testing, or require that some or all tests are performed again on the modified collector. The Solar Keymark network is continuously developing the certification scheme to make design changes easier and, as a result, some absorber coatings and glazing are interchangeable without any requirements for re-testing. The plan is to extend this concept to other materials and components.

[2] www.solarkeymark.org
[3] www.solar-rating.org

THE TESTS

Test categories

- Performance testing, type testing
  This requires experienced laboratory personnel and first class measuring equipment (with traceable calibration for irradiance, fluid flow rate and temperature difference across the collector) to achieve accurate, high quality results.
- Development testing
  This is less demanding on personnel and less advanced equipment is needed compared with the standard's requirements but then, of course, the level of instrument accuracy as well as accuracy in final results will be much lower.

TEST	PURPOSE	IN-HOUSE TESTING RECOMMENDED?
Internal pressure	To assess if the absorber can withstand the pressures which it might meet in service.	**Yes**, see guide section 5.2 and 9.2.1
High-temperature resistance	To assess if the collector can withstand stagnation under high irradiance levels without failures.	**Yes**, see guide section 5.3 and 9.2.2
Exposure	A short term ageing test aimed at sorting out low quality products. Collector in stagnation for minimum 30 days.	**Yes**, see guide section 5.4 and 9.2.3
External thermal shock	To assess the capability of a collector to withstand a severe thermal shock that can result from a sudden rainstorm on a hot sunny day.	**Yes**, see guide section 5.5 and 9.2.4
Internal thermal shock	To assess the capability of a collector to withstand a severe thermal shock that can result from an intake of cold heat transfer fluid a hot sunny day.	**Yes**, see guide section 5.6 and 9.2.5
Rain penetration	To assess if glazed collectors are substantially resistant to rain penetration.	**Yes**, see guide section 5.7 and 9.2.6
Freeze resistance	To assess if a collector which is claimed to be freeze resistant can withstand freezing and freeze/thaw cycling.	**No**, see guide section 5.8 and 9.2.7
Mechanical load	To assess the extent to which the transparent cover and the collector box are able to resist the positive and negative pressure load due to the effect of wind and snow.	**Yes**, see guide section 5.9 and 9.2.8
Impact resistance (optional)	To assess the extent to which a collector can withstand the effects of heavy impacts caused by hailstones.	**Yes**, see guide section 5.10 and 9.2.9
Final inspection	To assess any severe failures such as permanent deformation of components resulting from the tests above.	**Yes**, see guide section, 5.11 and 9.2.10
Thermal performance	To assess how energy can be gained from the collector at different temperatures, irradiances and more.	**No**, not recommended, see guide section 6

Note! Several safety procedures must be followed when testing solar collectors, see section 4.5 of the guide.

OTHER STANDARDS

Other relevant standards and references to EN 12975

Two important standards are directly related to EN 12975. This standard being referred to in both the EN 12976 dealing with factory made "compact" systems and in the EN 12977 series concerning custom-built "site assembled" systems. Furthermore, the EN ISO 9488 contains a solar thermal technical glossary and the ISO 9060 includes criteria for radiation measurement equipment. For further information on the EN 12975 standard scientific background, please refer to the standard's bibliography section.

A rough comparison with other solar thermal collector standards

There is a number of different standards describing solar thermal collectors testing. Historically, an American ASHRAE standard (93-77) was the first to be widely used. Then the ISO 9806 series of standards was developed and from this the EN 12975. Several national standards are available outside Europe, mostly based on the ISO 9806, whereas in Europe the EN 12975 has superseded all national standards. Currently, the aim of CEN and ISO is to revise the ISO 9806 based on new knowledge gained during the development of the EN 12975 standard. The major differences between EN 12975 and other commonly used standards are explained in section 2.1 of the guide.

A solar tracker facilitates performance testing, in particular when determining optical efficiency and incidence angle modifiers

TEST PROCEDURES FOR LIQUID HEATING SOLAR COLLECTORS AND SOME DEFINITIONS

Solar collector types covered by the standard

The standard covers performance, durability and reliability testing of almost all collector types available on the market. Tracking concentrating collectors have been recently included in the standard's scope. In the upcoming revision of the standard, air collectors and PVT collectors will also be incorporated; however, for the latter the standard will not apply to the collector's electrical components. Currently, only collector types covered by the EN 12975 standard can obtain a Solar Keymark certificate.

Area definitions

Definitions for gross, aperture and absorber areas are given in ISO 9488:1999 and illustrated by examples in the guide. It is important to understand that the efficiency and energy output of a collector is related to the area definition. In other words, depending on how the reference area is defined, the collector may seem more or less efficient. However, the output of a given collector module is the same, irrespective of the area definition used.

RELIABILITY TESTS

Purpose and "time" schedule for the different tests

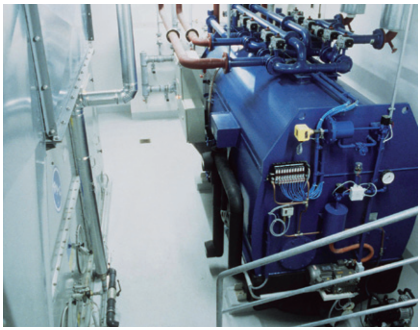
Over their lifetime, collectors will be exposed to some severe climatic and working conditions and it is stipulated that collectors must not suffer **Major Failures** when these conditions occur. Reliability and durability tests were designed to reproduce the most likely extreme conditions that a collector will be subjected to. The standard describes in a very simple way the conditions that are intended to be simulated for each test.

Under the current version of the standard, it is possible to reduce testing time by having three sample collectors tested simultaneously:

One collector for thermal performance

The standard indicates that the thermal performance test shall be carried out on a collector that has not been used for the other tests. This collector is only subjected to a short preconditioning with five hours exposure to irradiance above 700 Wm^{-2} before measuring the performance.

Mechanical load testing and outdoor exposure for a minimum of 30 days are examples of quality tests included in the EN 12975 standard



One collector for high-temperature resistance, exposure, thermal shocks together with a final inspection

The standard does not impose a sequence in the durability tests but indicates that high-temperature resistance and exposure test shall be carried out on the same collector. The standard also requests that thermal shocks may be combined with the high-temperature resistance and exposure test which is a good compromise between the number of samples to be tested and the time needed for testing.

One collector for mechanical loads and rain penetration

Although the current version of the standard allows the use of a third collector for the mechanical load and rain penetration test, this third sample must be submitted to a pre-conditioning in the case of rain penetration taking into account the decision D8.M10 of the Solar Keymark Network (see www.solarkeymark.org).

It can also be noted that when testing for durability and reliability, according to standards ISO 9806 and standard 100 for SRCC certification, the approach is different. The sequence is well defined in this case, all tests are carried out on the same collector and the performance test will be the final one in the sequence.

During the reliability tests no Major Failure shall occur. The definition of Major Failure is given in section 5.3, part 1 of the standard. These definitions and tests, where they are most likely to be identified, are shown in the table below.

DEFINITION OF MAJOR FAILURE	TEST WHERE IT IS MORE LIKELY TO OCCUR
Absorber leakage or such deformation that permanent contact between absorber and cover is established	Internal pressure, exposure test, internal thermal shock impact resistance, mechanical load test
Breaking or permanent deformation of cover or cover fixings	High temperature resistance test, exposure, internal thermal shock, impact resistance, mechanical load tests and external thermal shock
Breaking or permanent deformation of collector fixing points or collector box	Impact resistance and mechanical load tests
Vacuum loss, such that vacuum or sub atmospheric collectors shall be classified according to the definition in EN ISO 9488 (only applicable for vacuum and sub atmospheric collectors).	High temperature resistance test, exposure, impact resistance, mechanical load tests and external thermal shock
Accumulation of humidity in form of condensate on the inside of the transparent cover of the collector exceeding 10% of the aperture area.	External thermal shock and rain penetration test

THERMAL PERFORMANCE TESTS

Two generically different methods are allowed by the standard to determine the thermal performance characteristics of solar collectors: The Steady State method ("SS") and the Quasi Dynamic Test method, ("QDT"). Both methods can be used when testing for Solar Keymark certification. SRCC certification, however, only relies on the SS method for certification of non-concentrating collectors and on QDT for concentrating collectors. SS testing has been used over decades; whereas QDT was introduced in 2001when the first edition of EN 12975 was published. Both methods have their advantages and drawbacks; however, these two methods are considered to give comparable results for most collectors on the market. Comparing results derived by the two different methods should however not be done on the basis of individual parameters but on calculated annual energy output figures only.

In a performance test, optical and thermal properties of the collector are determined. The most important of these are presented as the "zero loss" coefficient $\eta 0$ and heat loss coefficients a_1 and a_2 (SS) or c_1 and c_2 (QDT). Additionally, the Incidence Angle Modifier (IAM) is a correction factor representing how the angle of incoming radiation affects the performance. Depending on the type of collector, additional correction factors can be important.

A collector that fulfills the requirements of the EN 12975 standard and is granted the Solar Keymark is a good investment for it's owner and for the environment

UNDERSTANDING THE TEST RESULTS

Comparing different collectors

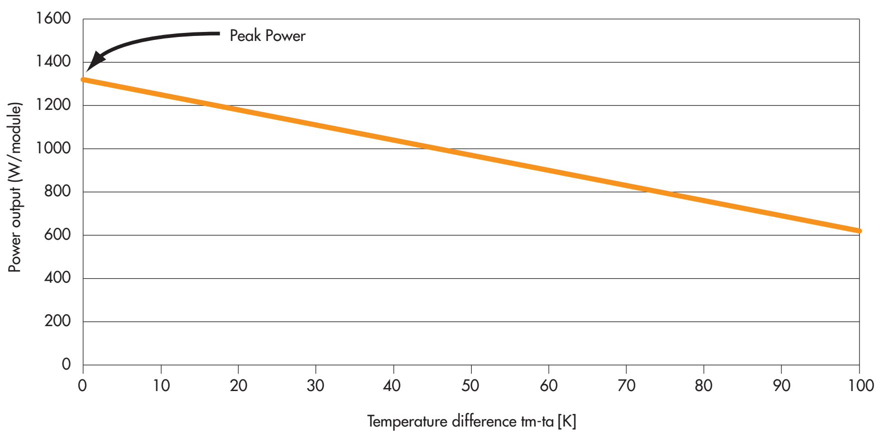
Collectors should not be compared on the basis of single model parameters (coefficients or correction factors) obtained from testing. These parameters are mainly used in a complete collector model for calculation of energy gained and for power output from the collector in different kinds of installations. Therefore, the best way to compare collectors is to calculate the useful energy from a square meter of collector or a whole module under similar climate and load conditions. The Solar Keymark data sheet now includes the calculated annual energy output for certified collectors using four different standardized climates and three different operating temperatures.

The power curve

The power curve is an alternative way of illustrating the collector's efficiency. It shows the power of a solar collector in relation to the temperature difference between the mean temperature of heat transfer fluid tm and the ambient temperature ta. The temperature difference is plotted on the x-axis and the collector power on the y-axis. For unglazed collectors three power curves are plotted showing results under different wind speeds.

The power curve is calculated with the efficiency parameters at normal incidence and based on the collector module and not on a specified area. The power values are normalized to a1000W/m² irradiation. The highest power is delivered at the point where no temperature difference between the mean temperature of the heat transfer fluid and the ambient temperature exists (t_m-t_a=0).

Power output per collector unit [W]



Equation for calculating the power per collector unit:

$$\dot{Q} = AG^*(\eta_0 - \frac{a_1(t_m - t_a)}{G^*} - \frac{a_2(t_m - t_a)^2}{G^*})$$

Figure 1. The power output curve shows the collector module power output as a function of the temperature difference (collector mean temperature-ambient temperature)

Annual energy output

Another way of illustrating the collector performance is by calculating the annual energy output from the collector using collector model parameters derived from performance tests, together with well-defined climate data and operating conditions. From 2012 onwards, all new Solar Keymark collector datasheets will include annual energy output figures for four locations and three operating temperatures.

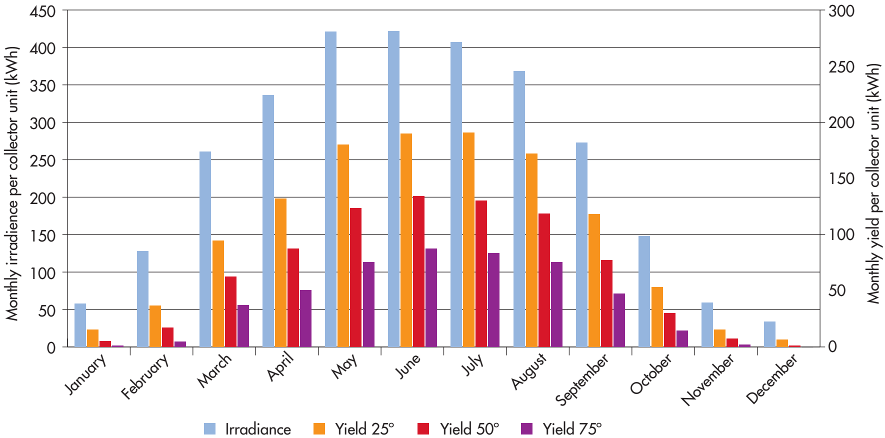


Figure 2. The annual energy yield per collector module is presented for four locations and three mean temperatures in the Solar Keymark collector data sheet.

Optional pressure drop

For solar collector systems designers, the pressure drop across a collector may be of importance (e.g. for sizing of pumps). The pressure drop between the collector inlet and outlet is shown in the pressure drop curve at different flow rates. The pressure drop curve is normally a quadratic function of the fluid mass-flow rate, which means, that the pressure drop increases with the square of the mass flow rate.

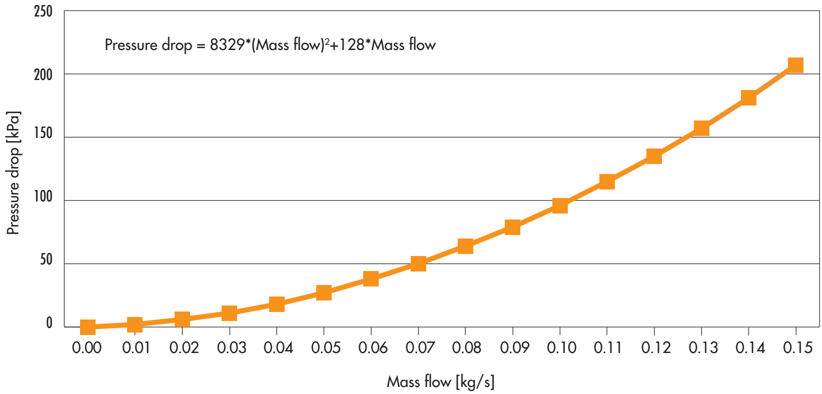


Figure 3. Pressure drop is an optional test in the standard. Different heat transfer fluids give different curves

Durability and reliability test results

The standard requires that test reports include a table containing the performed tests, date performed and a summary of the main results. In the "Summary of main test results", the test laboratory will indicate one of the following options; *No failure or Pass*, *No Major Failure or Pass* otherwise *Major Failure or Fail*.

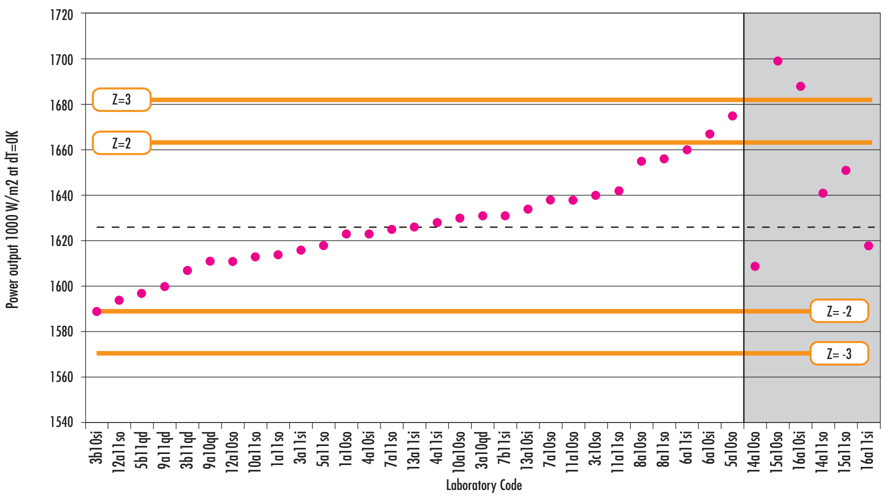
In cases of no major failure or major failure, the relevant section of the test report will be given and shall include a description of what occurred during testing. For *Major Failure* the manufacturer will have to decide which modifications should be made to the Product or changes in the Manufacturing process; new tests will then be necessary for final approval of the product.

In cases of *No major failure*, a minor problem has occurred (see sections 5.2 to 5.10 of the guide). The manufacturer should analyze carefully the problem as described by the Laboratory and consider whether he should introduce modifications to the Product or changes in the Manufacturing process. If this is undertaken, the Certification body must be informed for a joint evaluation with the Laboratory to see if tests need to be rerun.

Measurement and calculation uncertainties

The overall standard uncertainty in solar collector efficiency values, determined by an accredited test laboratory, is about 3%. The uncertainty in calculated energy gain is even higher and could exceed 10% depending on the operating temperature and test method applied. The higher uncertainty in calculated energy gain is due to the climatic data used for this calculation and interannual climate variability. This must always be taken into consideration when reading test reports and designing solar thermal installations. One should also bear in mind that the uncertainty of final results involves many elements: measurement uncertainty during testing, model uncertainties, manufacturing/ material property uncertainties, etc. Further information on this topic is provided in the guide.

Results from measurements on a flat plate collector by twelve laboratories within the QAiST project show that the measurements are of very high quality. Laboratories to the right of the vertical line are not accredited and thus cannot perform measurements for Solar Keymark certification.



10 &11 represents measurements carried out during 2010 and 2011   si = steady state test indoors   so = Steady state test outdoors   qd = Quasi Dynamic testing

CONCLUDING REMARKS

This document, "Understanding and using collector test standard", is one of several publications issued by the project "Quality Assurance in Solar Heating and Cooling Technology" (QAiST). The goal of this project, supported by the European Commission through the Intelligent Energy Europe programme, was to put in place a quality assurance framework so that the European solar thermal heating and cooling industry can sustainably contribute to the targets agreed by the Member States (20% of RES by 2020) and become a technological world leader.

Accordingly, it was decided to produce guidelines for standard EN 12975, aimed at solar thermal testing laboratories. This decision was taken because this standard is continuously evolving, both in scope and complexity, as well as the products assessed against it. While many new laboratories have started or will be starting testing in the near future, their staff often lack experience in this kind of testing and in the application of this standard. Therefore, the objective was to give a uniform interpretation of the standard; enable harmonized presentation of the final results and to support new laboratories entering the solar thermal sector.

It was also decided that, besides such guidelines, a shorter and simpler version should be made available to non-experts to help understand the standard, its requirements and implications, as well as make the test results easier to analyse.

This document has been compiled by a group of solar thermal experts involved in the QAiST project and we would like to express our gratitude to those who contributed to its drafting and production.

We hope it will assist the reader in his or her professional activity. Please note that further useful information may be found on the QAiST project, Solar Keymark Network or ESTIF websites.

FURTHER READING

- QAiST IEE/08/593/SI2.529236 Deliverable D 2.3
  A guideline to the standard EN 12975
- CEN, European committee for standardization, 2006
  "EN 12975-1:2006, Thermal solar systems and components - Collectors - Part 1: Requirements"
- CEN, European committee for standardization, 2006
  "EN 12975-2:2006, Thermal solar systems and components - Collectors - Part 2: Test methods"
- www.solarkeymark.org
- www.cen.eu
- www.estif.org
- www.iso.org
- www.qaist.eu

Class A instruments are required when accredited laboratories perform tests according to EN 12975

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