SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

IEA-SHC TASK 43: SOLAR RATING AND CERTIFICATION PROCEDURES

White Paper on Low-to-Medium Temperature Collectors

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Authors: Korbinian Kramer, Stephan Fischer, Peter Kovacs
Participants: Fraunhofer ISE, ITW, SP
Contributing Editor: Les Nelson, IAPMO

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1 INTRODUCTION

1.1 Description of Work Carried Out

From 2010 through 2012, under the auspices of the EU-funded QAiST (**Q**uality **A**ssurance in **S**olar Thermal Heating and Cooling **T**echnology) project, 12 laboratories participated in a proficiency test designed to identify the repeatability and conformity of solar testing laboratories results. One part of this effort involved low to medium temperature solar collector testing. The results of this work form an important part of the Task 43 work as it relates in international harmonization, in that examining the accuracy and repeatability of solar collector tests, as well as identifying problem areas, will lead to a good basis for harmonization.

1.2 Status of Work on Low to Medium Temperature Collector Standards

Within the last three years a harmonisation of international standards into one globally accepted ISO Standard was prepared. Since the initiative was European driven, the work started within the European working group for product standards on solar thermal collectors (CEN/TC 312 WG1). The goal was to develop a revision of ISO 9806, partially based on the EN 12975 standard, to incorporate:

- Available technologies not yet included
- Improvements on testing methodologies
- Improved reliability and comparability provisions
- Consensus interests of all stakeholders

A primary focus was the desire to eliminate market barriers and enhance global trade by developing an international standard possibly leading to a global certification scheme. Several meetings of the TC 180 and CEN/TC 312 Technical Committees, as well as input from the IEA Task 45 participants contributed to the process, and international input was solicited. The resulting EN ISO 9806 standard is now complete from a technical perspective, and will be voted on during summer 2013. A vote of approval will lead to publishing of the final standard by early 2014.

It should be noted that important topics of secondary priority are not included in the updated standard, so the work is not complete, and in fact will never be complete given ongoing innovation in the marketplace. In the following chapters the significant technical changes are described.

2 FLAT PLATE COLLECTORS (FPC) AND EVACUATED TUBE COLLECTORS (ETC): DURABILITY & RELIABILITY REQUIREMENTS AND TEST METHODS

2.1 Exposure Test

The exposure test has been re-organized. While the basic assumptions on duration and insolation remain the same, the test methodology is more flexible, leading to This quicker testing periods. A hybrid (indoor/outdoor) procedure has been developed, which will accelerate the testing process during times of unsatisfactory weather conditions (although possibly at a higher cost).

Although not reflected in the new draft standard, examination of a long term 2 year exposure test has begun. Initial results indicate a strong need for accelerated testing procedures for heat pipe ETCs and ETCs in general(1 year aging) already could show the tremendous need of accelerated aging of heat-pipes. The Chinese standardization organization has offered to take a lead in these work issues, however China is not a participant in Task 43.

2.2 Internal Pressure Test

The internal absorber pressure test is intended to assess the extent to which the absorber can withstand the pressures which it might meet in service while operating at elevated temperature. This is done by means of applying 1.5 times the maximum operating pressure at a temperature the absorber would reach when exposed to an irradiance of 1000 W/m² at 30°C ambient temperature. For metal based absorbers this test is conducted with an absorber having ambient temperature.

When the test temperature exceeds 90°C, the absorber may be connected to a hot oil circuit. The absorber and the hot oil circuit are then pressurised. The absorber may be heated by one of the following methods:

1. Connecting a heater in the oil circuit
2. Heating the whole collector in a solar simulator
3. Heating the whole collector outdoors under natural solar irradiance

Alternatively the absorber may be pressure tested using compressed air, when heated either in a solar simulator or under natural irradiance.

After 1 hour of testing at 1.5 times the maximum operation pressure at the temperature corresponding to an irradiance of 1000 W/m2 and 30°C ambient temperature the absorber will be inspected for leakage, swelling and distortion.

2.3 Rain Penetration Test

Two methods are accepted for this test. Method 1 uses the weighing procedure defined in EN 12975. The second method is to perform the rain penetration test at the end of the performance test and subsequently conduct a final inspection. The rain application procedure is based on AS/NZS 2712, and improves the repeatability of this important test.

2.4 Mechanical Load Test

At the time of this writing, this test procedure was still under development. The load amount used in the standard is identical to the load amount in IEC 61215. This helps to harmonize production guidelines and test equipment and provides critical information for system designers. The methodology of the mechanical load test and its applicability to all types of products in the scope of the standard will continue to require refinement as new product configurations are developed. In addition, the current load test method neglects important real life effects, and therefore is not perfectly suitable for the product standard. On-going work is needed to clearly define the boundaries of solar collector standards and roofing standards as they apply to mounting hardware. Work along these lines is being accomplished through a working group established between CEN TC 312, CEN TC 128/TC254, and other technical committees.

2.5 Impact Resistance Test

The impact resistance test has been drafted to be mandatory for all collectors, which constitutes a major change. Two parallel procedures were drafted. Method 1 defines a procedure for using an ice ball propelled from a gun-like device, based on IEC 61215 and on Switzerland's existing procedure, where hail resistance testing is mandatory. Method 2 uses a steel ball dropped on the collector, as defined in the recent EN standard update. Although these two methods are not perfectly comparable from a physics perspective, a compromise to allow both was reached.

2.6 Freeze Resistance Test

This test is intended to assess the extent to which evacuated tube collectors using heat pipes can withstand freezing and freezing/ thaw cycles. This test is independent from the statement, that the collector may only be used with anti-freeze liquid as there's a closed second liquid loop within the heat-pipe with the risk of freezing. This procedure is applicable to heat pipes integrated into single glass tubes as well as to those integrated into all glass tubes.[1]

2.7 Final Inspection

The final inspection is perhaps the most important aspect of durability and reliability testing. Each part and component of the collector is disassembled and closely inspected. It is at this stage of testing that most pass/fail issues are encountered. The general component/issue areas

[1] SOLAR KEYMARK SCHEME RULES ANNEX F
Requirements for freeze resistance test of evacuated tube collectors with Heat Pipes following EN 12975:2006

from the QAiST Guide to Standard EN 12975, which is very similar to the draft EN ISO 9806, are set forth in Table 1.

Table 1: Annex B5.5 of EN 12975-2:2006

Collector component	Potential problem	Evaluation
Collector box /fastener	Cracking / warping / corrosion / rain penetration	0/1/2
Mountings / structure	Strength / Safety	0/1/2
Seals / gaskets	Cracking / adhesion / elasticity	0/1/2
Cover / reflector	Cracking / crazing / buckling / delaminating / warping / outgassing	0/1/2
Absorber coating	Cracking / crazing / blistering	0/1/2
Absorber tubes and manifold boxes	Deformation / corrosion / leakage / loss of bonding	0/1/2
Absorber mountings	Deformation / corrosion	0/1/2
Insulation	Water retention / outgassing / degradation	0/1/2

0: No problem, 1: Minor problem, 2: Severe problem, x: Inspection to establish the condition was not possible

3 FPC-ETC COLLECTORS: ROUND ROBIN TESTS (QAIST)

Inter-laboratory comparison testing is an important aspect of quality assurance of testing laboratories.[2] The confidence in the test results is essential for the market and a sine-qua-non condition for the development of quality assurance.

Consumers, industry and public authorities need to trust that testing, and the results provided in the test results are reliable and comparable, even when performed in different parts of Europe. For instance, within the Solar Keymark network the industry should be as flexible as possible in the choice of test laboratories and inspection bodies. Even if only the results of accredited test labs and inspectors will be accepted, it is essential for the mutual acceptance of test results that the tests and inspections that are carried out have a uniform quality level. In order to ensure this, common quality assurance measures will be carried out within the involved test labs and inspection bodies.

Round robin testing has been conducted previously, although the results and gained experience of these tests showed the need for further improvement of the Round Robin test procedure and further quality assurance of the testing itself.

[2] See EN ISO/IEC 17025:2005, Section 5.9

Reviewing some of the previous work, some gaps or shortcomings had been identified. On one side the round robin had not been managed by an independent body. Furthermore, no precise criteria have been defined and executed. Finally, the analysis of test results was hardly possible due to lack of data and information executed.

The round robin test for solar collectors (12 participants) and solar thermal systems (9 participants) can be considered as the largest ever carried out in the field of solar thermal technology. In addition, for the first time ever, this round robin was evaluated by an independent institute (Institut für Eignungsprüfung, IfEP) using the acknowledged procedures for the evaluation of proficiency tests. Figure 1 below shows an example of a tested flat plate collector.

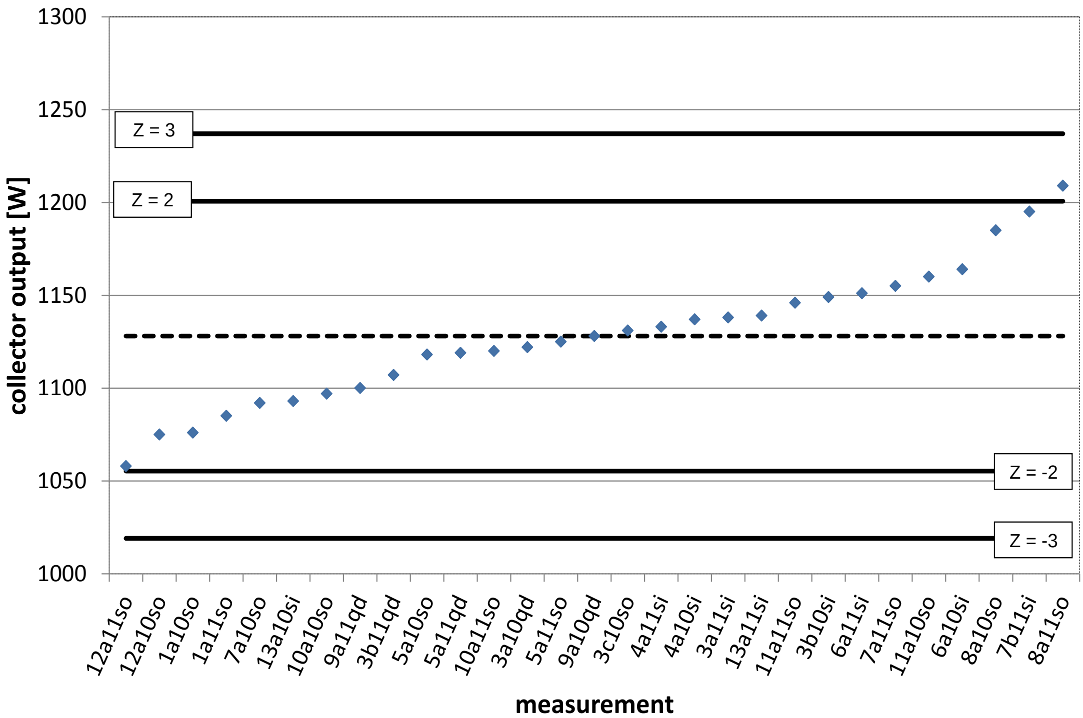


Figure 1: QAiST round robin laboratory test results for a collector

The evaluation was carried out using the so called Z-score with the following thresholds:

|Z| ≤ 2 satisfactory participated
|Z| ≥ 3 unsatisfactory participated
2 < |Z| < 3 result questionable

IfEP considered the overall result as very good although different test procedures (e.g. steady state and quasi dynamic) were used.

> *"12 laboratories from 8 European nations participated in the proficiency test "QAiST testing of solar collectors and solar systems 2010-2011" that was evaluated by Institut für Eignungsprüfung (IfEP GmbH) in Marl, Germany.*
>
> *The results submitted in 2010 and 2011 were evaluated on basis of a robust statistical method, in order to minimize the influence of outliers regarding individual laboratory mean values. The total results show very good results. Although the tasks were very complex, the results were close together.*
>
> *Compared to other proficiency tests in the field of mechanical testing the results are clearly better. The number of unsatisfactory results is clearly lower. This shows a very good quality of work in the participating laboratories. It gives a conclusion of the high level of training of personnel and the high quality of the standards used."*[3]

The results, presented in a sound scientific manner, allow for an estimation of the precision of the test results, and help industry understand reasons for and confidence in this precision.

The process included two rounds of round robins (one in 2010 and one in 2011), with an interim report allowing for adjustment and improvement of the procedures through interaction with the test laboratories.

In brief, the round robin test for collectors and systems was successfully accomplished and it shows the excellent work done by the participating test laboratories.

3.1 Outlook and Future Opportunities

The round robin tests performed within QAiST are considered to be the first step for continuing such exercises in the future. Further detailed analysis of round robin data will be accomplished involving all test labs. This will be done to further improve the quality of measurements. The first exercise will be carried out within the framework of the Solar Keymark network, where the participants can discuss in detail the differences between the results to further improve the procedures. It will be important to implement round robins on a regular basis to maintain the quality of testing.

[3] Extract from IfEP report (Full report including all results can be found in the ANNEX)

4 POLYMERIC MATERIAL COLLECTORS

This chapter lists and describes the tests according to EN 12975-2.2006 which might be problematic for collectors using polymeric materials.
The tests in question are:

1. Internal absorber pressure test (EN 12975-2:2006, clause 5.2)
2. High temperature resistance test (EN 12975-2:2006, clause 5.3)
3. Exposure test (EN 12975-2:2006, clause 5.4)
4. Mechanical load test (EN 12975-2:2006, clause 5.9)
5. Impact resistance test (EN 12975-2:2006, clause 5.10)
6. Performance testing of collectors having discontinuous efficiency curves (EN 12975-2:2006, clause 6.1 and 6.3)

4.1 Internal Absorber Pressure Test

The internal pressure test provisions outlined in Section 2.2 above apply to polymeric collectors as well, however difficulties are encountered during testing in regards to keeping the test pressure constant during one hour due to expansion of the polymer during the test under high temperature. It should be noted that metallic absorbers can be pressure tested at ambient conditions. The method for assessing the extent to which the absorber can withstand pressures at elevated temperature can be considered as adequate. However compared to the absorber pressure test of metal based absorbers the costs are higher due to the additional requirements related to the higher temperatures. Thus a method should be found that would allow a test under ambient temperature.[4]

4.2 Exposure and High Temperature Resistance Test

The exposure test and the high-temperature resistance test are not only a potential problem for polymeric collectors but also for all other collector types.

Potential defects caused by these tests can be:

- Breakage, tearing, bending, lumps or fatigue of material at the collector casing and covers
- Interference of sealings
- Depositions caused by outgassing of collector materials
- Staining of collector materials caused by degradation

[4] Stephan Fischer, Polymeric Materials for Solar Thermal Applications

Comments on Possible Alternative Procedures

Some polymers degrade when exposed to UV, water and heat or a combination thereof. Depending on the exact composition of the used polymeric materials, it will take shorter or longer until visible or non-visible degradation occurs.

Considering the variety of different materials and their different reaction to ambient loads and taking into account the fact that there is only very limited experience with long-time exposure of polymeric collectors, it is currently neither possible nor advisable to change the exposure times in the existing standards.

Nevertheless, in the future, it may be necessary to revise the existing exposure loads for polymeric collectors in order to assure meaningful and realistic testing.

Besides long-term monitoring of various collectors, it is therefore recommended to conduct research in the area of materials and collector testing including accelerated aging tests that might ultimately be suitable to provide more concise information about long-term durability and therefore might indicate the need for altered exposure conditions for polymeric collectors.

If a polymeric collector does not have an adequate efficiency at higher temperatures it could be possible that the collector is not able to evaporate all the fluid in stagnation. Thus, the high-temperature resistance test with an unfilled absorber is not a real simulation of the operating condition of the collector. Nevertheless, this situation does not exclusively apply to polymeric collectors.[5]

4.3 Performance Test, Thermotropic Layers, Natural and/or Forced Ventilation

Within EN 12975-2, the tests and calculation procedures set forth below are concerned by discontinuous efficiency curves of polymeric collectors with temperature limiting measures, such as thermotropic layers, temperature-controlled ventilation, or other active or passive measures.

In the following chapters of EN12975 second-order dependencies on the temperature difference (tm - ta) (tm: middle temperature of the fluid in the collector, ta: ambient temperature) are established:

6.1.4.8 Computation of collector output	Formulas (7), (8)
6.3.4.8.2 The Collector Model	Formula (32)
6.3.4.8.4 Graphical presentation of test results	Formula (32.1)
D.3 Test results	Formulas (D.3), (D.4)
Annex H: Comparison of the collector model of 6.1 to the collector model of 6.3	Formulas (H.1), (H.2)

A simple linear dependency on this temperature difference is established in:

C.2 Determination of stagnation temperature	Formula (C.1)

[5] Christoph Zauner, Philippe Papillon; Polymeric Materials for Solar Thermal Applications

Potential Issues

The tests and computations above may not reflect the requirements for polymeric (and other) collectors if they have optical or mechanical measures to limit the temperature of the absorber.[6]

5 COLLECTOR ENERGY OUTPUT

Different user groups such as system designers, private consumers and others need easily understandable and comparable data on the energy performance of solar thermal collectors. Therefore it is convenient to convert test parameters for a specific collector into an energy performance figure using a reference climate and some sort of mathematical collector model. Several national approaches to this conversion have been developed but in order to find a European or even globally harmonized approach, a common tool and procedure was developed within the QAiST project

5.1 Method for Calculating Annual Performance of Collectors

The Excel-based "Scenocalc"[7] tool has been developed as a benchmark for collector energy output in order to have comparisons on a common ground. The direct compatibility to EN12975 Quasi dynamic test (QDT) results and, after applying built in corrections, also to Steady State (SS) test results, is a big advantage of this tool as it removes several uncertainty sources on the way from test data to annual energy output figures. The international cooperation and agreement to use the tool in the Solar Keymark scheme rules is also an important step towards harmonized results.

To make the calculation tool more easily accepted, the equations used in the tool are put together from the well-known solar textbook Duffie and Beckman (2006) or journal publications Braun (1983), Fisher (2004), Mc Intire (1983), Theunissen (1985). The equations are fully defined and described in a document available together with the Scenocalc software. In addition, work has been done to exactly select and define the climate input data, including ground albedo (0.2), as well as to describe the procedure to calculate global, beam and diffuse radiation onto a fixed, tilted or tracking collector plane. These factors together constitute a major portion of differences between simulation tools, which range from +/-10%.

The Scenocalc tool addresses all collector designs on the market except ICS (integral collector storage) collectors, where the built in storage with a very large time delay needs a special thermal capacitance correction. The software addresses unglazed, evacuated tube, low, medium and high concentration collectors, as well as flat plate collectors. Calculations can be

6 Robert Hausner, Polymeric Materials for Solar Thermal Applications
7 http://www.sp.se/en/index/services/solar/ScenoCalc/Sidor/default.aspx

performed for any collector tilt and orientation as well as for some common tracking product designs.

The Scenocalc tool includes detailed documentation, is transparent and allows for an independent comparison with other tools. Such comparisons were carried out in the QAiST project showing that the Scenocalc model provides results that are as accurate as the most complex TRNSYS collector models.

The tool calculates the energy output from solar thermal collectors based on weather data from four European locations: Stockholm, Würzburg, Davos and Athens. The tool can directly use parameters derived from collector tests according to EN 12975. The tool calculates the collector gain at three user defined operating temperatures which are assumed to be constant over the year. The collector tilt and orientation is adjustable, and standard tracking options are available. Scenocalc produces energy output figures and a output diagram on an annual and monthly basis by default, however hourly values can also be accessed. It is also possible to add new locations for the user. The calculation procedure results in an output screen as shown in Figure 2.

Results from the Energy Output Calculator

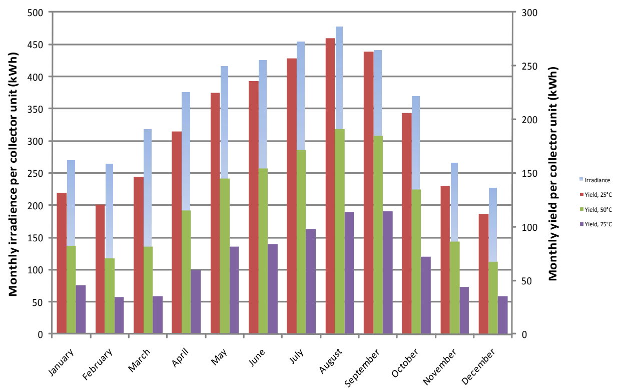
Version 3.0 (TRIAL VERSION THAT HAS NOT BEEN VALIDATED, Feb, 2011)

Identification label for the solar collector: Not specified

Date of evaluation: 11 August, 2011

Monthly irradiance and yield per collector unit (kWh)

	Irradiance	Yield (three collector mean temperatures)		
		25°C	50°C	75°C
January	269	132	82	45
February	264	120	70	35
March	317	147	81	35
April	375	189	115	60
May	416	225	145	81
June	425	236	154	84
July	453	257	171	98
August	476	276	191	113
September	440	263	185	115
October	368	206	134	72
November	265	138	86	44
December	226	112	67	35
Year	**4 294**	**2 300**	**1 484**	**818**



Location: Athens
Longitude: -23.73
Latitude: 38.00
Climate data, time period: 1996-2005

Collector information (all inputs are based on aperture)
Aperture area: 2.5 m²
Evaluation method: Quasi Dynamic Testing
$F'(\tau\ \alpha)_{en}$ 0.85
$K_{\theta,\ d}$ 0.9 $(\Rightarrow \eta_0 = F'(\tau\ \alpha)_{en} \cdot (K_{\theta,\ b}(15°) \cdot 0.85 + K_{\theta,\ d} \cdot 0.15) = 0.835)$
c_1 3.5 W/m² K $\Rightarrow a_1 = c_1 + 3 \cdot c_3 = 4.1$ W/m²K (including wind 3 m/s)
c_2 0.015 W/m² K² $\Rightarrow a_2 = c_2 = 0.015$ W/m²K²
c_3 0.2 J/m³ K
c_4 0.5 [--]
c_6 0.05 s/m
wind correction 0.5
Type of tracking: No tracking
IAM Type: Simple, one-direction
$b_0 = 0.1$

Figure 2: The result screen in Scenocalc showing monthly and annual energy output figures for one location and three operating temperatures.

6 TEXT PROPOSALS FOR ISO 9806 STANDARD REVISION

Numerous proposals have been submitted by stakeholders regarding the draft version of ISO 9806:2012; these were submitted for public examination, inquiry and comment, and some have been accepted and incorporated in the draft standard. The opportunity for major comments on the structure of the new draft has passed as of this writing, however minor changes of an editorial nature may still be incorporated in the final text.

7 SUBTASK A ROADMAP CONTENT RELATED TO LOW-TO-MEDIUM TEMPERATURE COLLECTOR TEST PROCEDURES

There are several different test methods for solar thermal collector characterization and certification. These include the American standard ASHRAE 93-77, the international standard ISO 9806-1 and the European standard EN12975-2. These procedures test the reliability and efficiency of solar thermal collectors. The thermal performance characterization test methods for solar collectors differ mainly in the duration time of the testing period, the testing conditions, and the mean temperature of the working fluid.

7.1 Flat Plate Collectors

Flat-plate solar collectors absorb solar radiation and transfer the energy to a working fluid without concentrating the incident radiation before absorption, hence capturing both the direct and diffuse solar radiation.

The main flat plate collector components are the transmission cover, the absorber plate and the insulated casing. The transparent cover is used to reduce convection losses from the absorber plate by means of the stagnant air layer between the absorber plate and the glass. The cover also reduces radiation losses from the collector, since the glass is transparent to the short wave sunlight radiation but is nearly opaque to the long-wave thermal radiation emitted by the absorber plate.

A flat-plate collector has a large heat absorbing area, however it has the highest heat loss of all low to medium temperature collector types except for unglazed collectors, which is why its use is usually limited to low temperature applications less than 80ºC. This collector type does not require sun-tracking and is typically affixed to a sloped structure oriented directly south, where the optimum tilt angle is approximately equal to the latitude of the location.

7.1.1 Current standards and certification procedures

The main applicable standards are ISO 9806-1, EN 12975 and ASHRAE 93, as described in Section 2.

7.1.2 Gaps and open questions

The exposure test according to the European standard has been under debate, mainly due to the inability to maintain uniform test conditions all over Europe. Exposure tests over 30 days according to the European standard EN-12975-2 remain in question.

The rain penetration test according to the European Standard has 3 different criteria to define if a collector passes the test or not (by weighing the collector, by means of humidity measurement or by means of measuring the condensation level). These 3 different criteria do not guarantee uniform testing results among all European laboratories. Also, existing procedures for performance testing of collectors - for certain types of collectors - do not yield accurate performance characterization when “non-typical“ flow rates are used.

7.1.3 Testing approaches

CEN/TC312

A proposal from the French laboratory CSTB recommending the extension of the exposure period for the accelerated aging test from 6 to 12 months has the disadvantage of being highly time consuming. Another option is the adoption of the Australian Standard AS/NZS 2535.1, which utilizes an improved short period exposure test.

Most participants in the EU-sponsored New Generation of Solar Thermal Systems (NEGST) project believe that a year-long test period is excessive, and recommend further investigation into the concept of using a test procedure similar to the Australian short term procedure. According to the resolution 6/2007, taken by CEN/TC 312, on 2007-10-15 & 16, Nicosia / Cyprus, the performance of flat plate collectors at non typical flow rates should be also studied.

7.2 Evacuated Tube Collectors

Evacuated tube collectors (ETC) consist of an absorbing surface mounted in a vacuum glass tube to eliminate convection heat loss. This collector is composed of an array of glass evacuated tubes using water as working fluid.

Types of evacuated tube collectors:

- Single glass tubes
- Double glass tubes
- ETC with direct connection
- ETC with heat pipe connection

Table 2. Specific features relevant to all types of ETCs[8]

Specific Feature	Implication on testing or system design
The comparatively low heat losses resulting in high stagnation and maximum operating temperatures	• Difficult to determine efficiency at high temperatures with good accuracy • Difficult to determine unambiguous stagnation temperature • Special attention required in system design in order to avoid thermal stress on heat transfer fluids
The non-planar shape of the collector surface, whether fitted with a reflector or not	• Difficult to determine proper loads for mechanical load testing • Bi- or multi-axial incidence angle modifiers need to be determined in performance testing
The frequent use of (external) reflector mirrors	• Highly exposed component having a high influence on the performance which is not assessed in present test standards • Difficult to assess the effects on collector output over the long term
The fragile structure of the vacuum tubes	• Impact resistance testing required in some regions
The fact that the performance is heavily dependent on the quality (level, durability) of the vacuum	• Difficult to determine vacuum loss during quality tests • Difficult to assess the long term durability of the vacuum

7.2.1 Current standards and certification procedures

There is no specific test standard for ETC; the testing methodologies used for ETC are standards which were first written for flat plate solar collectors. Most standards do not consider the geometric and thermal behaviour of ETCs.

The main difference between ETCs and flat-plate collectors in the European standard EN 12975-2 involves the incidence angle modifier measurement.

Evacuated FPC and ETC for water heating applications at temperatures under 100ºC can be tested under the ISO 9806-1. But in order to test their efficiency at low radiation levels, the test procedures for ETC are performed with dynamic methods.

7.2.2 Gaps and open questions

There are still gaps in the standards regarding the definitions and specifications of ETCs. In addition, there are shortcomings in the thermal performance model, the capacitance determination, the mechanical load and impact resistance tests, the freeze testing of heat pipes and the durability of the glass to metal seal.

The slope of the efficiency curve for an evacuated collector is low resulting from the elimination of convective heat losses. The efficiency model is not accurate, for example, for

8 Recommendations on testing evacuated tube collectors (ETCs). EU NEGST WP4 document D2.1.b at http://www.swt-technologie.de/html/publicdeliverables3.html

double-glass evacuated tube collectors and the measurement of the absorber temperature is difficult to perform in practice.

The method of defining the absorber area of an ETC appeared in the former version of the European Standard EN 12975-2, however it does not appear in the 2006 version.

The method of evaluation of thermal capacitance is not fully accurate. With the calculation method, according to part 6.1.6.2, it is underestimated and with the quasi-dynamic test it is overestimated.

The mechanical load test is not performed for evacuated tubes without reflectors by most European laboratories, although it is advisable for a positive load test to be performed in circumstances where the product will be used in snowy regions. For example, wood pellets can be used to simulate snow behaviour (see NEGST Project).

The impact resistance test is also not well-defined for ETCs with either ice or steel balls.

Finally, the issue of vacuum loss over time is not addressed at all under the available standards. This important quality parameter should be tested in some way that is yet to be defined.

7.2.3 Testing approaches[9]

- Study possible new models for efficiency curve.
- Define the incidence angle and impact location for hail ball impact tests.
- Define a test method to evaluate vacuum losses.
- Thermal capacitance modelling of ETCs has been reviewed in the Eurosol project and will be taken into consideration in the revision of EN 12975.
- For the IAM test, there are difficulties for heat-pipes; in a simulator, very accurate collimation is required, in a sun-tracker the changing tilt creates problems, and with a south-facing test bench it is difficult to obtain a 50º longitudinal angle.

7.3 Polymeric Material Collectors

Conventional solar collector systems are based on materials (e.g. copper) with high prices and limited availability. The material supplies may not be adequate for the expected growth in solar thermal installations. These issues demand the introduction of new materials, of which polymers have received substantial attention. Polymers have a significant cost reduction potential due to mass production manufacturing processes, low weight, and flexibility in structural and functional design. These factors have the potential to lead to a breakthrough in solar collector production.

Polymeric collectors had a market share of 11% of the worldwide solar heating capacity in operation in 2010, almost exclusively unglazed absorbers for swimming pool heating. The

[9] NEGST WP4 document D2.1.b at http://www.swt-technologie.de/html/publicdeliverables3.html

USA has the largest market for polymeric pool heating absorbers with an energy production of 13.6 GWth in operation at the end of 2010. Pool heating absorbers operate in the low temperature range. In order to meet the requirements from the market for heating applications in the medium and high temperature range, the introduction of new polymeric materials and technology is essential. New materials can only be applied if the service life is comparable to those in conventional products.

Polymeric unglazed absorbers for (outdoor) swimming pool heating have been used successfully in the market for more than 30 years. However there are few commercial glazed collectors with polymeric absorbers. Those that exist are mostly designed for low-pressure systems, which are vented to the atmosphere and use water without antifreeze additives as the heat transfer fluid. Depending on the application, polymeric absorbers use different system designs as compared with conventional, metal-based absorbers. For example, some designs incorporate a built-in overheat/freezing protection mechanism for the solar collectors, such as drain-back technology or ventilation to avoid thermal stagnation or freezing of the heat transfer fluid in the solar loop.

The use of polymeric materials allows for new production techniques, as well as new types of features such as smart-snap designs, for example. Many examples exist where polymeric collectors, due to shape, innovative design, or simply due to the material itself, can have added value for purposes such as building integration.

The applications of polymeric materials as collector components include:

- **Unglazed absorbers,** with existing high market penetration as swimming pool heating absorbers, include rigid, extruded sheets of polypropylene (PP) with integral heat transfer passages, or designs utilizing plain polyethylene (PE) pipes, for example.
- **Glazing**, which must be able to maintain its mechanical and transmissivity properties despite the temperature gradient between the internal collector case and the ambient temperature, as well as solar irradiation and mechanical loads due to wind, snow, hail and rain. Comprehensive work on the durability of polymeric glazing has been performed, in Subtask C of IEA-SHC Task 39, where UV-resistant, thermotropic and anti-soiling coatings for polymeric surfaces are examined.
- **Glazed absorbers.** Examples include a thermosiphon collector with a blow-moulded absorber of PE, flat-plate collectors with 10 mm polycarbonate (PC) twin-wall sheet collector covers, or modular systems of polymeric or hybrid-polymeric collectors, which are available in various lengths and designed to replace conventional roof- or facade covers.
- **Integral collector storage (ICS)** designs. For example, ICS with polypropylene casing and transparent insulation of cellulose triacetate, a moulded storage container in polyethylene, PC glazing with a copper heat exchanger or a cylindrical tank under a transparent dome of PMMA with an inner, upper shell of PC and an outer, rear shell of HD-PE.

- **Collector frame materials**, low weight and easy installation are major advantages of polymeric materials for collector frames and casings.

7.3.1 Current standards and certification procedures

ISO 9806 and ASHRAE 93 standards can be used, but their tests methods are not suitable for solar water heaters with an integrated storage system.

The EN 12975 Standard can be used, however its scope is limited for testing polymeric innovations, and it is not suitable for solar water heaters with an integrated storage system. Limitations of EN 12975 regarding polymer innovations are described:

(1) In the performance test, the quadratic performance equation fails to represent thermal step change panels using thermochromic or thermostatic air vents.

(2) In the durability test, the limitations are:

   a. description of polymers as organic, thus excluding silicone rubber which is inorganic;

   b. use of absolute instead of functional pass-fail criteria, thereby undervaluing the flexibility of polymers;

   c. incorrect test assumption that the peak pressures in water filled freeze tolerant collectors coincide with high temperature stagnation, when instead peak pressures may occur under freezing conditions;

(3) The exposure test requires dry panels to stagnate for 30 days, but some polymer panels are continually pumped at high temperatures (and they dump heat to prevent boiling at low light levels).

7.3.2 Gaps and open questions

Thermal stagnation and the risk of overheating is avoided in systems utilizing polymeric collectors is avoided with built-in overheat prevention mechanisms, allowing the use of low-cost commodity plastics in glazed collectors. Several overheating control strategies include:

- Natural or forced ventilation of the collector between absorber/glazing or absorber/thermal insulation.
- Absorber materials or thermotropic coatings which change from transparent to opaque at a critical temperature for the absorber material. Coatings could be applied either on the glazing to reduce the transmittance or on the absorber to reduce the absorptance once a critical temperatures is reached.
- Change of the refraction index of the collector glazing by a simple mechanism that reduces the solar radiation transmittance.

To justify the high cost of solar thermal systems, extended product life of more than 20 years is required. To date however, most producers of polymeric glazing materials do not present reliable data on the ageing performance of their products over such a long time period.

7.3.3 Testing approaches

The weathering[10] properties of poly(methyl methacrylate) (PMMA) have been shown to be in the range of glass or even slightly better. Contrarily, material degradation was observed for polyvinyl chloride (PC), polyethylene terephthalate (PET), polyvinyl chloride (PVC) and unsaturated polyester (UP). Soiling was strongly dependent on the exposure site and the glazing material. At the suburban site of Rapperswil (CH) a significant loss in solar transmittance in the range of 3-15% was measured. Testing of fluoropolymers such as ethylene tetrafluoroethylene (ETFE) revealed surprisingly high losses in transmittance; fluorinated ethylene propylene (FEP) and polyvinyl fluoride (PVF) exhibited a tendency for soil accumulation.

The NEGST project recommends that the Swedish SP-method[11] be used as a basis for potential future standardisation work on plastic and rubber components in solar collectors, including absorbers, reflectors, cover glazings and frames. With certain adjustments the method can be applied to other polymeric material components, such as pipe systems and sealings. The goal of the method is to ensure a 15-year lifetime of components by long-term analysis of their mechanical characteristics, absorption and transmittance. In combination with other requirements, the method is intended to be used as a basis for P-marking of solar collectors.

7.4 Actions

The EU project QAiST: **Q**uality **A**ssurance **i**n **S**olar **T**hermal Heating and Cooling Technology has several activities within its WP2: solar thermal collectors with almost the same goals as Task 43 Subtask A, applying to the extension of the EN standards. This project working activities have been used as a starting point for the definition of the action plan for Subtask A.

The QAiST WP2 goals are:

- Extending the scope of EN 12975 to fully cover medium temperature collectors (tracking, concentrating collectors, evacuated tube collectors)
- Clarification and strengthening of durability and reliability requirements and test methods in EN 12975
- Enhanced quality assurance of collector testing

[10] F. Ruesch, S. Brunold, Ageing Performance of Collector Glazing Materials – Results from 20 Years of Outdoor Weathering. 338 - Eurosun 2008 Proceedings.

[11] Polymeric materials in solar collectors - Test methods and technical requirements", Department of Chemistry and Materials Technology Borås 2004, Leo Spilg

- Harmonized energy output calculations

The WP2 includes the following tasks:

- T2.1: Definition of appropriate requirements and test methods for:
  - Tracking and/ or concentrating collectors (mid- temperature collectors)
  - Durability testing and assessment of collectors and collector components
- T2.2: A guide to Standard EN 12975 (completed)
- T2.3: Performance calculation tool (completed)

8 ANNEX 1. FINAL REPORT – PROFICIENCY TEST; QAiST TESTING OF SOLAR COLLECTORS AND SYSTEMS 2010-2011