# IEA-SHC PROGRAMME TASK 43: RESEARCH ON SOLAR COLLECTOR AND SYSTEM TESTING AND CERTIFICATION

**Kevin DeGroat[1], Jan-Erik Nielsen[2], Les Nelson[3], Harald Drueck[4] and Enric Mateu [5]**

[1] Antares Group, Inc. 4351 Garden City Drive, Landover, MD United States of America, 01+301-789-7768, kdegroat@antares.org

[2] PlanEnergi, Aggerupvej 1, 4330 Hvalsoe, Denmark

[3]Western Renewables Group, 30012 Aventura, Suite A, Rancho Seco Margarita, CA 92688, USA 01+949-713-3500

[4]Institute for Thermodynamics and Thermal Engineering (ITW), University Stuttgart Pfaffenwaldring 6, 70550 Stuttgart, Germany

[5] Solar Thermal Energy Department, National Renewable Energy Centre (CENER), Ciudad de la Innovación 7, 31621, Sarriguren (Navarra), Spain

## Synopsis

Europe, North America, Australia and many individual countries have certification and testing procedures for solar thermal equipment designed to protect consumers from poor performance and unsafe designs. Most certification bodies rely on outside tests, which have much in common from country to country but may not be exactly identical. Most certification bodies only recognize tests from laboratories they certify and that follow their technical specifications although most testing is based on the same ISO standards worldwide. Testing has not kept up with all the new technologies and system applications, creating a barrier to market innovation because access to incentives and markets for new products is often tied to certification. Governments rely on certification to ensure incentives are given to effective products, and testing laboratories and certification bodies are struggling to keep up with demand. The IEA-SHC Programme (IEA-SHC) Task 43 is organizing research into testing procedures for SHC collectors and systems, round-robin testing and sharing of research results among testing laboratories. The results of this work is offered to certification bodies in Australia, Europe, and North America to promote harmonization of testing standards, cooperation in certifying SHC products and wider acceptance of lab test results between countries.

## 1 Task 43 Purpose

This international collaboration is researching and developing, where needed, new test procedures and characterization methods for addressing the testing of both conventional and advanced solar thermal products. It has collected information from existing IEA-SHC Tasks, technical committees of standards organizations, and certification bodies as a base for the work. These groups have also been invited to participate through workshops and joint meetings, which have already included the Solar Keymark Network, International Standards Organization Technical Committee 180 (ISO/TC180) and expert meetings in South Africa and Germany. By researching testing issues and improved approaches the outputs of this task are intended to reduce the time and resources companies, laboratories and certification bodies expend on testing and certification; while still assuring consumer protection and providing credible information on solar heating and cooling benefits. The scope of this proposed task includes performance testing and characterization, qualification testing, environmental impact assessment, accelerated aging tests, numerical and analytical modelling, component substitution procedures, and entire system assessment. A specific objective of the task is to influence the ISO and the European Committee for Standardization (CEN) work to as much as possible harmonize ISO and European Standards (EN) for solar thermal collectors and systems. The possibilities for establishing a common worldwide certification scheme for solar thermal collectors that would continue to promote global standardization will also be investigated.

## 2 Task 43 Methods

The overall approach to this task is to identify leading researchers in various types of collectors and systems and identify the implications of their work for testing standards and certification. The task is shared among the participating countries with each covering the costs of its own research under the task as well as time and travel required for task coordination. So far there are 9 countries actively participating, 9 industry observers, and interest from an additional 10 institutions/countries.

A cross-cutting effort led by the two Operating Agents (one from Europe and one from North America) is developing a proposal for a global certification body that could be a vehicle for applying the results of Subtasks A and B to harmonize standards and certification requirements for SHC products internationally. The concept has been discussed at conferences, ISO/TC180 meetings and the 67$^{th}$ IEA-SHC Executive Committee meeting to solicit feedback and support.

Subtask A on collectors is coordinating existing research and supporting new efforts to examine existing testing and certification procedures for low-temperature evacuated tube collectors (ETC) and flat-plate collectors, air heating collectors, and medium- to high-temperature concentrating collectors to identify weaknesses, inconsistencies in application, and significant gaps. The research will result in new or improved tests that can be communicated to ISO/TC 180 for consideration in updating existing standards or developing new standards. Results will be promoted to certification bodies when they are relevant for consideration in how product certification is implemented. Methods include round robin tests to refine existing test procedures in cooperation with researchers, industry and certification bodies involved in these technologies. The task will also establish ongoing information dissemination and communications to provide necessary information and feedback among participants, industry, and certification bodies to promote harmonized standards and coordination among certification bodies.

Subtask B on systems is examining existing test procedures for entire systems and identifying weaknesses, inconsistencies in application, and significant gaps. It will organize existing research or initiate new efforts to investigate component/material substitution issues, including implications for qualification and safety testing. System performance characterization, testing, simulation and modeling and extrapolation will be investigated to help clarify key issues including accelerated aging testing and performance prediction. The research will extend to analyzing how system testing and performance characterization results can be applied to analysis and dissemination of public benefit indicators, including environmental, economic, and energy metrics for solar thermal systems. Where appropriate, research results that have implications for testing standards will be communicated to ISO/TC 180 and/or certification bodies to consider. The subtask will also establish ongoing information dissemination and communications to provide necessary information and feedback among participants, industry, and certification bodies to harmonize standards and procedures.

## 3 Task 43 Results

Task 43 has been active less than one year, but has already produced two valuable roadmaps to testing and certification issues for collectors (Subtask A) and systems (Subtask B). There have been two technical workshops and an industry workshop to engage industry and certification bodies in the Task as well. Papers and reference materials are being organized on the IEA-SHC Programme website and on a Wiki-enabled website to encourage researchers and experts in testing and certification issues to use the results and recommendations of the work. Although it is still early, the degree of communication between ISO/TC-180, Solar Keymark, the Solar Rating and Certification Corporation (SRCC) in North America and Australian researchers and regulatory bodies has already increased through joint meetings and active participation in the Subtasks. So far there have been two task expert meetings, one in South Africa in conjunction with ISO/TC180 and the latest in Stuttgart, Germany in conjunction with an open workshop on solar thermal and heat pumps, where technical issues for Subtask A and B were discussed and work assignments and deadlines were settled.

### 3.1 Global Certification Scheme

The cross-cutting effort to develop a global certification body has created a concept for a global body that would incorporate members from individual country or regional certification bodies to share best practices, agree on common practices and standards, and work to reduce barriers to product certification across borders. Existing models for this type of body have been identified and information collected on how they are organized, sanctioned, and operated. Several important issues, and proposed responses, have been identified:

- Resistance from existing national certification bodies because of concerns over their revenues and authorities. A proposed solution is to emphasize that existing bodies will still collect fees for certification in specific countries; harmonization would mainly reduce the need for re-testing of equipment by labs.

- Variation in climate, hazards and operating conditions in different countries create legitimate demands for different testing and certification. A proposed solution is to develop a menu of test classifications at an international level that national certification bodies could use to construct a flexible approach that matches local conditions. For example, a country or locality could require a more rigorous but standard test for hail resistance in areas prone to damaging hail, while another area with no threat could choose a standard but less rigorous test level. Collectors and systems would receive ratings appropriate to the level of test applied, and the test levels and procedures would be agreed to by all participants in the global certification scheme.
- An issue with "category" ratings is that any class needs a break between one class and another, so there is always an incentive for a "Class B" product to do a little more to make it into "Class A." If they are not carefully constructed this border problem can mask real differences between a top-end "Class A" product in a category and a product that barely met the standards for the classification. Carefully constructing the classifications so that distinctions between classes are as clear as possible is the proposed solution.
- Nations or regions are tempted to add "extra" requirements to existing standards to serve a perceived need or simply to create trade barriers. A proposed solution is to provide the global certification body with membership standards and mechanisms to discourage "extra" national requirements on top of the standards that are globally accepted, and making the classification system broad and flexible enough so that it can address real differences in local conditions.

### 3.2 Subtask A Collectors

Subtask A focuses on collectors and is organizing research on low-temperature evacuated tube and flat-plate collectors, air-heating collectors, and medium-to-high temperature concentrating collectors. This subtask has already generated a "roadmap" of testing and performance issues for these collectors and identified existing research that will be leveraged to create a series of white papers on key testing issues for dissemination and discussion with other test labs and certification bodies. Participants are also active in the European Union Quality Assurance in solar thermal heating and cooling technology (QAiST) round-robin collector testing. The Subtask leader has recruited North American and Australian test labs to participate in the round-robin tests as well to expand their impact beyond Europe. The Subtask A roadmap on collector testing has been prepared and discussed with task participants and was accepted as the basis for organizing the Subtask A research efforts. The roadmap is expected to be presented to the next IEA-SHC Executive Committee meeting for review and then publication on the IEA-SHC website. ISO/TC180 and CEN Technical Committee 312 (TC 312) have agreed to work towards a common harmonized standard for collector testing.

The work plan for low temperature collectors address the gaps and open questions in testing and certification of collectors, particularly exposure testing and uniform test conditions across Europe, North America and Australia. Issues specific to evacuated tube collectors are summarized in Table 1 on the next page. Many arise from the application of test methods written for flat plate collectors that don't consider the impact of ETC geometry and thermal specific behavior. Based on analysis of key testing issues, Subtask A research activities are focused on thermal performance modeling, capacitance determination, mechanical load, impact resistance, freeze testing and durability of glass/metal seals.

For polymeric collectors thermal stagnation testing is an issue. Thermal stagnation and risk for overheating is generally avoided in any collector systems using metal-based- or polymeric collectors. The intention with a built-in overheating mechanism for polymeric collectors is to be able to use low-cost commodity plastics in glazed collectors protected by overheating control strategies including:

- Natural or forced ventilation of the collector between absorber/glazing or absorber/thermal insulation.
- Functional materials / thermotropic coatings that switch from transparent to opaque at a critical temperature for the absorber material Tc. The coating can be applied on the glazing to reduce transmittance or on the absorber to reduce absorptance for temperatures above Tc.
- Changing the refraction index of the collector glazing by a simple mechanism that reduces solar radiation transmittance.

To justify the high investments for a solar thermal system, generally a long lifetime in the range of more than 20 years has to be ensured. However, up to now most producers of polymeric glazing materials do not present reliable data on the ageing performance of their products over such a long time period.

Table 1: Common ETC Characteristics and Issues

| Specific feature | Implication on testing or system design |
|---|---|
| The comparatively low heat losses resulting in high stagnation- and maximum operation temperatures | • Difficult to determine efficiency at high temperatures with good accuracy<br>• Difficult to determine unambiguous stagnation temperature<br>• Special attention required in system design in order to avoid thermal stress on the heat transfer fluid |
| The non planar shape of the collector surface, either it is fitted with a reflector or not | • Difficult to determine proper loads for mechanical load tests<br>• 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 but not being assessed in present test standards<br>• Difficult to assess the long term effects on the collector output |
| 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 in connection to quality tests<br>• Difficult to assess the long term durability of the vacuum |

To address these gaps and inconsistencies, work has started on exposure tests including internal pressure and rain tests (results due 01/2011), mechanical load (10/2011), impact resistance (01/2011), pressure drop (01/2011), freezing resistance (10/2011) and component testing including safety and structural issues (01/2011). Work on solar fluid testing procedures is planned but not started (02/2012). Results from round-robin testing under QAiST will also be incorporated into Subtask A. Both the Florida Solar Energy Center (FSEC) and Exova in North America have committed to participating in the round robin testing (02/2012). Work in polymeric material collectors to investigate internal pressure, exposure and high temperature resistance, and collector energy output are in progress (02/2012). Recommendations on test standards (02/2012) and a final white paper on issues (02/2012) have not started, pending preliminary results from the other activities. This work builds off earlier results from IEA-SHC Task 39, Polymeric Materials for Solar Thermal Applications.

Air heating collectors have limited standardized test procedures, mainly the Italian Standard UNI 8937 and the US-American Standard ASHRAE 93-2003. Starting a standardization process for testing solar air collectors has been discussed in ISO/TC180, but no further steps have been taken. A critical area for new test procedures is wind dependency. The performance of some collectors, especially uncovered but also collectors with the air flow directly under the cover, are strongly dependent on wind. Existing standard for testing water collectors recommend procedures for wind simulation, but are not sufficient for air collectors. For example, for uncovered collectors the direction of the wind can influence performance. Further research on the impact of air speed is needed for defining new test procedures to determine the wind dependency in order to have a standard covering the needs of all stakeholders. Other research topics include:

- Internal pressure tests for collectors:
    - How relevant are pressure tests for air collectors?.
    - Is it possible to reach relevant over pressure under real conditions?
    - Internal pressure test may be dropped for open absorbers (i.e. transpired air collectors)
- Fluid inlet temperature:
    - Air collectors in combination with heat pumps can have an inlet temperature range starting at -20°C.
    - How relevant are these testing conditions for air collectors?
    - Is it applicable to chill down the testing environment to -20°C?

Work has been assigned but not started in the review of performance models, testing procedures and standards (12/2010), revision of the standard scope (02/2012) and performance test procedures (02/2012).

In concentrating collectors the parameter definitions of current standards should be extended to include new concentrating developments and emerging concepts. The current standards are mainly focused on different testing methodologies for determining the concentrator collector thermal performance, using outdoor steady state or quasi-dynamic methods. Less developed are the durability or qualification tests methods for concentrator collectors. The lack of a specific standard, leads to a wide range of durability test possibilities causing the following problems:

- Need to review a wide range of durability test standards from other technology fields to perform tailor made durability tests which are adapted from several “selected” standards.
- Difficulties to compare durability test results from different manufacturers or testing laboratories, because they are based on different standards or testing conditions.
- No common definition for accelerated test exposure conditions that can differ a lot from service life conditions. Microclimate characterization and degradation factors also need to be assessed.
- Validation of predicted service life through outdoor exposure tests or data from their components or materials service life, where reliable test results are obtained, in most cases, after a new material is commercially launched.

Work has been assigned and is in progress on definitions and requirements (08/2010), review of performance models and test procedures (08/2010), performance test parameters and conditions (02/2012), and concentrator collector tests (02/2012). Work is planned but not yet started in collector component characterization, durability, and reliability (02/2012), the recommendations on test standards resulting from the research (02/2012) and the final white paper on issues in concentrator collector testing (02/2012). Table 2 below presents the major thermal efficiency test standards in use and their scope in relation to collectors.

Table 2: Thermal Efficiency Test Standards

| Test Standard | | Scope |
|---|---|---|
| ASHRAE 96 | Test methods: | • Steady state<br>• Outdoor and indoor |
| | Collectors: | • Flat plate<br>• Unglazed |
| | Heat transfer fluids: | • Liquid |
| ISO 9806-3 | Test methods: | • Steady state<br>• Outdoor and indoor |
| | Collectors: | • Unglazed |
| | Heat transfer fluids: | • Liquid |
| | Exceptions: | • Collectors with integrated thermal storage unit<br>• Collectors with phase change of heat transfer fluid |
| EN 12975-2: Chapter 6.1 (steady state) | Test methods: | • Steady state<br>• Outdoor and indoor |
| | Collectors: | • Unglazed |
| | Heat transfer fluids: | • Liquid |
| | Exceptions: | • Collectors with integrated thermal storage unit<br>• Tracking concentrating |
| EN 12975-2: Chapter 6.3 (dynamic) | Test methods: | • Dynamic<br>• Outdoor |
| | Collectors: | • Glazed and unglazed<br>• Nonconcentrating and concentrating[1] |
| | Heat transfer fluids: | • Liquid |
| | Exceptions: | • Collectors with integrated thermal storage unit |

### 3.3 Subtask B Systems

Subtask B is identifying current research and organizing new research to explore issues in testing and characterization of entire systems. This Subtask has already generated a draft roadmap of research issues including component/material substitution, qualification and safety testing issues, performance characterization, and accelerated aging tests. Research participants are sharing their results and will contribute to a series of white papers targeted to testing laboratories to disseminate their findings and recommendations on testing standards.

Task 43 participants are interested in solar thermal terminology and vocabulary, particularly related to the boundaries of what can be considered a system for testing. Several participants are active with ISO/TC180 Working Group 1 which is revising ISO 9488 and will coordinate between ISO and Task 43 work.

Round robin testing and performance based test methods were discussed extensively. The Canadian Standards Association (CSA), SRCC, and ISO/TC180 are all involved with this topic. The Florida Solar Energy Center was due to submit a revised draft standard on performance based test methods in mid-March, which will then be reviewed one more time before becoming an official draft standard. The Consistent Cycle Test (CCT, used mostly in Europe) and OG300 (used by SRCC in the US) offer different approaches to performance testing of systems that need to be compared to better understand the strengths and weaknesses of each.

Heat pumps integrated with solar thermal systems is of great interest, and was recently added to Subtask B activities. SRCC in North America is moving fast to develop testing and certification because of the demand from new product manufacturers. This raises concerns that whatever they produce could become a precedent, before there has been time to examine the issues and experiment with different testing approaches. There are questions concerning whether the solar thermal element of the systems can be adequately tested and characterized separately from the components that integrate it with the heat pump elements of a system, and whether size extrapolations are sound for characterizing different system sizes. Yet industry cannot wait 1-2 years for appropriate testing standards to be developed and incorporated into certification schemes. Heat pump industry groups and participants in IEA-SHC Task 44 on Solar Heat Pump Systems need to be involved to leverage the resources that are already working on this issue.

Component material and substitution standards are applied to collectors, but there are no parallels for system-level substitutions for stores, controllers, pumps and other system elements. While the US allows applicants to change stores and pumps and other elements and then reevaluate using TRNSYS, there is no guidance on what is allowed or not allowed.

Work that has been completed or initiated includes:

- Results of a meeting of experts to discuss solar thermal systems testing and characterization issues and develop detailed research recommendations. (Target Date: 10/2010. Accomplished 2/2010 in Stuttgart meeting)
- A white paper detailing the results of research on the effects of component/material substitution and extrapolating size have on actual system performance versus predictions and recommendations on how tests and standards for systems need to be adapted. (Target Date: 6/2010 for a draft)
- A report on norms for systems testing and characterization that addresses system boundaries and definitions. (Target Date: 6/2010
- A report on qualification and safety testing that identifies inconsistencies, gaps and problems and recommends actions to resolve key issues. (Target Date: 9/2010)
- A white paper on simulation and modeling tools that identify strengths, weaknesses, gaps in their capabilities, and inconsistencies in their application or interpretation. (Target Date: 10/2010, survey of tools completed early in March 15, 2010)
- A report examining the relation between test and characterization information and user experience – for example, testing and measurement as it relates to occupant comfort in space conditioning – with recommendations for improvements or new approaches. (Target Date: 5/2010. Target date moved to 2012, end of task, due to dependence on other activities)
- A report examining the connection between solar thermal system testing and measurement and measures of the public benefits of solar thermal systems, with recommendations for making testing, measurement and certification more effective as a foundation for benefits estimates. (Target Date: 1/2010, Target date moved to 2012, end of task, due to dependence on other activities)

## 4 Summary and Next Steps

Task 43 is still in the early stages of actual research and developing results that can be used to improve and harmonize collector and system testing standards. Plans are still being developed as to how it may influence certification to remove barriers to SHC products between continents and countries. The current participants are still recruiting to expand involvement to make the effort more successful. First, greater participation from industry members and trade groups is needed to build support for harmonization, and to ensure that industry concerns with testing and certification are represented. Representation from China, India, Latin America and Africa is being actively sought because they represent major SHC markets and manufacturing centers. They could be impacted significantly, and they could have a major influence on, harmonizing standards for testing SHC collectors and systems, and how those tests are applied in certification schemes in existing and emerging markets. Seeking to improve and harmonize testing standards is mainly an issue of agreeing how tests should be performed and what they mean, which in turn creates a basis for consumers, policy makers and other stakeholders to understand and evaluate different products based on their preferences and needs. Consumers and stakeholders will desire different performance and cost characteristics based on the climate, economy, and culture that prevails in their country or region, so there is wide room for different products. However, all stakeholders including industry benefits from common standards and tests that help stakeholders fairly compare competing products and ensure minimum levels of performance, durability, and safety at the least cost for testing and certification possible.

## 5 References


[1] EN 12975-1,2:2006 „Thermal solar systems and components – Solar collectors“

[2] EN 12976-1,2:2006 „Thermal solar systems and components – Factory made systems“

[3] ENV 12977-1,2,3:2001 „Thermal solar systems and components – Custom built systems“

[4] ISO 9459-5: 2007 „Solar heating – Domestic water heating systems – Part 5“

[5] International Energy Agency Solar Heating and Cooling Programme, http://www.iea-shc.org/index.html

[6] QAiST:Quality Assurance in Solar Heating and Cooling Technology, http://www.estif.org/projects/ongoing_projects/qaist/project_summary/