SCF II Project

Procedures for the certification of performance of large custom-made solar thermal systems, with particular emphasis on the modelling tools (SK-LCMSTS)

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Guidelines for the certification of performance of large custom-made solar thermal systems

S. Babalis, J.E. Nielsen

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1. Introduction

Quality assurance is of primary importance for *large custom built systems*. The total investment cost for such systems is higher than for smaller ones, although the specific investment cost (i.e., per m^2 collector area) is lower. In several European countries, the potential of large custom-built systems, from the point of view of conventional energy savings, is much larger than for smaller ones. Moreover, the return on investment is in many cases more favourable for large systems than for small ones. Hence, both the purchasers of large custom-built systems and the governments are interested in efficient, reliable and durable systems, the thermal performance of which may be accurately predicted, checked and monitored.

Dealing with the above issues and in view of the availability of the EN 12977 series standard for custom-built systems, the integration of the Solar Keymark Scheme Rules, by implementing the "*large custom-built systems*" becomes a necessary prerequisite for the further development in this field of applications.

The aim of this project regards the elaboration of rules for the certification of *large custom-built solar thermal systems* (as defined in the EN 12977 Standard series), in the framework of the Solar Keymark resulting in efficient, reliable and durable systems, the thermal performance of which may be predicted, checked and supervised.

Subsequently, the various aspects dealing with the implementation of the Solar Keymark Scheme Rules, based on the requirements of the EN 12977-1 Standard and the provisions for testings and / or checks of the EN 12977-2 one, are investigated. Specific requirements and provisions for the application of the Standards on the *large custom-built solar thermal systems*, dealing with the possible problems arising during the practical application, are also reported.

2. Classification of solar heating systems

Solar heating systems, as described in the EN 12976 and EN 12977 series Standards, are distinguished in two categories:

- *Factory-made solar heating systems* are batch products with one trade name, sold as complete and ready to install kits, with fixed configurations. Systems of this category are considered as a single product and assessed as a whole. If a factory made solar heating system is modified by changing its configuration or by changing one or more of its components, the modified system is considered as a new system.
- *Custom-built solar heating systems* are either uniquely built or assembled by choosing from an assortment of components. Systems of this category are regarded as a set of components. Requirements for custom built solar heating systems are given in EN 12977-1.

Custom-built solar heating systems are subdivided into two categories:

a) Small custom-built systems

Small custom-built systems offered by a company are described in a so-called assortment file, in which all components and possible system configurations, marketed by the company, are specified. Each possible combination of a system configuration with components from the assortment is considered as one custom built system. In general, the collector area is greater than 1 m^2 and less than 30 m^3 and the store volume is less than 3 m^3

b) Large custom built systems (L.C.B.S.T.S.)

Large custom-built systems, defined as those uniquely designed by combining various components for a specific situation which could be used either for hot water preparation and/or space heating/cooling. In general, the collector area is greater than 30 m^2 and the store volume is greater than 3 m^3.

Large custom built systems are classified as follows.

Class	Purpose
A	*A system in which the store(s) and the collector array(s) are located in one building for which the heat/cool is provided. No seasonal store and no heat/cool distribution network outside the building are included.*
B	*A system which consists of a central heating/cooling plant and one or more collector array(s). The heat/cool is transported via a heat/cool distribution network to the heating plant and/or to other buildings. No seasonal store is included.*
C	*A large custom built system which mainly consists of one or more large collector array(s) and in which the heat/cool is transferred to a seasonal store or directly into a heat/cool distribution network.*
D	*Others*

3. General Requirements

The requirements *for large custom-built systems*, as stated in the EN 12977-1 Standard, refer to the methods given in EN 12977-2 and EN 12977-4.

3.1 Suitability for drinking water

Requirements by EN 12977-1:
Conformity to the EN 806-1 and EN 806-2 Standards is required.

Discussion: Given that *large custom-built systems* are designed for specific applications, therefore only installations used for hot water preparation (hotels, large residential buildings etc.) shall comply with this requirement. For systems used for space heating/cooling applications this requirement is not applicable.

SKM implementation:
No physical test is required; a declaration from the manufacturer that in the design of the system the requirements of the EN 806-1 and -2 Standard have been taken into consideration shall be required.

See section 7 for Documentation requirements.

3.2 Water contamination

Requirements by EN 12977-1:
The system has to be designed in order to avoid water contamination from backflow from all circuits to cold supply.

SKM implementation:
No physical test is required. Check if the manufacturer in the installation and in the documentation for the installer includes provisions and instructions for the installation of the adequate means (usually a non return valve in an appropriate place is satisfactory) for preventing water contamination from backflow from all circuits to drinking main supplies.
See section 7 for Documentation requirements.

3.3 Freeze resistance

Requirements by EN 12977-1:

According to the EN 12976-1 Standard.

The manufacturer shall state a minimal allowed temperature for the system. The manufacturer shall describe the method of freeze protection used for the system. The parts of the system that are exposed to the outdoors shall be able to withstand freezing to this specified temperature without any permanent damage.

Any components that are to be installed in places where temperatures can drop below 0 °C, shall be protected against freezing.
The freezing mechanism shall be tested in accordance with 5.1 of EN 12976-2:2006.
If a freeze protection by means of antifreeze fluid is adopted then the manufacturer shall define the composition of the heat transfer fluid, including additives, allowed for the system.
Precautions shall be taken to prevent the antifreeze fluid from deterioration as a result of high temperature conditions. These precautions shall be checked in accordance with 5.2 of EN 12976-2:2006.

NOTE In general the minimal allowed temperature of the system is equal to the freezing point of the antifreeze fluid. If the concentration of some antifreeze fluids - like glycols - exceeds a certain limit, they can freeze without damaging the system. In this case the minimal allowed temperature can be lower than the freezing point of the antifreeze fluid.

<u>Discussion</u>:
Relevant requirements of EN 12976-1 shall be considered.
The manufacturer shall describe the method of freeze protection used for the system.
Usually *large custom-built systems* are operating by means of antifreeze fluid allowing therefore a minimal temperature of the system equal to the freezing point of the fluid adopted, as stated by the manufacturer.

<u>SKM implementation:</u>
There are many possible forms of protective provisions, and the testing authority shall first identify which method has been employed. The manufacturer shall define the antifreeze protective method adopted and this shall be checked and verified in the documentation.
Checks are given to ensure that suitable protective antifreezing provisions have been taken and they are operating properly. The provision shall then be checked in accordance with the appropriate section of the list in §5.1 of the EN 12976-2 Standard and in accordance to the manufacturer's recommendations.

3.4 High-temperature protection

<u>Requirements by EN 12977-1</u>:
Systems, in which the temperature of the domestic hot water delivered to the user can exceed 60 °C, shall be fitted with an automatic cold water mixing device or any other device to limit the temperature to at maximum 60 °C shall be installed.
The design of the system shall ensure that the highest permissible temperatures to which the system components may be exposed are not exceeded, taking into account also pressure conditions if relevant. Maximum temperature in the collector is the collector stagnation temperature according to the EN 12975-2 test report.

Discussion:
Very often, e.g. for systems used for space heating/cooling applications, this requirement is not applicable, because many of the subsystems adopted for cooling applications require a higher water temperature (e.g. absorber chillers require a temperature close to 80 °C) for reliable and optimal operation.

SKM implementation:
No physical test is required, only check.
Large custom-built systems used for hot water preparation shall comply with the scald protection requirement , of the EN 12977-1 Standard exclusively in the case that domestic hot water is directly delivered to the user.

The design of the system shall ensure that the highest permissible temperatures to which the system components may be exposed are not exceeded, taking into account also pressure conditions if relevant. Maximum temperature in the collector is the collector stagnation temperature according to the EN 12975-2 test report.

Care shall be taken in cases where under stagnation conditions steam or hot water can enter the collector pipes, pipework, distribution network or heat exchanger providing the system with the appropriate safety and regulating devices.

No testing is required; only checking of the hydraulic scheme and/or by calculation and taking into account the most adverse conditions for the materials of all parts of the system, that the maximum temperatures which may occur do not exceed the maximum permissible temperatures for the respective materials, taking into account also pressure conditions and/or mechanical stress if relevant.

3.5 Reverse circulation prevention

Requirements by EN 12977-1:
The installation of the system as described in the hydraulic scheme supplied by the manufacturer shall ensure that no unintentional reverse flow occurs in any hydraulic loop of the system.

SKM implementation:
No physical testing is required; only checking of the hydraulic scheme to ensure that adequate protection was taken (usually non-return valves).

3.6 Pressure resistance

Requirements by EN 12977-1:
The solar collectors, the storage tank and the heat exchangers shall withstand at least 1.5 times the manufacturer's stated maximum individual working pressures.

The drinking water circuit shall withstand the maximum pressure required by national/European drinking water regulations for open-vented or closed drinking water installations.

The system shall have been designed in such a way that the maximal allowed pressure of any materials in the system is never exceeded, taking into account temperature conditions if relevant.

Every closed circuit in the system shall contain safety valves. This safety valve shall withstand the highest temperature that can be reached at its location. It shall conform to EN 1489. If thermostatic valves are used, these shall conform to EN 1490.

Collector arrays of *large custom built systems* shall be designed in a way so that they can also withstand high-pressure peaks of short duration, e.g. arising from sudden evaporation of liquid within the collectors at the beginning of stagnation.

If, due to stagnation, considerable heat transfer medium quantities in the collector array evaporate, pressure peaks may occur due to high flow velocities of steam or liquid. These pressure peaks may significantly exceed the release pressure of the safety valve.

Discussion:

The working and maximum expected pressure of every circuit of the large custom built system shall be compatible with the pressure resistance specifications of all single components supplied by the manufacturer. For Solar Keymarked components information shall be taken by the relative certificates.
Documentation/declaration from the responsible installer that the requirements in the Pressure Equipment Directive (PED) for the system as a whole are fulfilled shall be available.

SKM implementation:
Check if certified pressure performance of collectors, stores and heat exchangers withstand at least 1.5 times the manufacturer's stated maximum individual working pressures. If not then testing procedures specified in §5.3 of the EN 12976-2:2006 standard shall be applied on the store(s) and the heat exchanger(s).

Check if the system documentation for the installer describes a pressure resistance test procedure for the collector loop of the system.

3.7 Electrical safety

Requirements by EN 12977-1:
All electrical appliances shall conform to the EN 60335-1 and EN 60335-2-21.
There shall be means to interrupt manually the power supply to the pump(s).

SKM implementation:
No physical test is required. Check if in the documentation for the installers the conformity to the EN 60335-1 and EN 60335-2-21 standard is clearly declared.

4. Requirements on Materials

Requirements by EN 12977-1:
It shall be stated in the documentation for the installers that materials exposed to weathering shall be resistant to rodents, birds, UV radiation and other weather conditions over a prescribed lifetime.

All materials used in the collector loop shall comply with ISO/TR 10217 in order to avoid any internal corrosion.

Discussion:

SKM implementation:
No physical test is required. Check if in the documentation for the installers the resistance of the materials is appropriately taken into consideration during the design of the system.

5. Requirements on Components and pipework

5.1 Collector and collector array

Requirements by EN 12977-1:
The collector shall meet the requirements given in EN 12975-1. For parts and joints of the collector array, see 5.8 for which care shall be taken in order to ensure long-term durability and tightness.

The collector array shall be checked with regard to flow distribution (usually the collector array includes several parallel connected rows of collectors) and the maximum divergent of the mass flow rate per unit collector area of each row shall not exceed 20 % of the nominal flow rate per unit collector area of the whole array, unless explicitly stated by the manufacturer.

The collector shall be tested according to EN 12975-2.

SKM implementation:
The collector shall be solar key-marked.
Flow distribution shall be checked and balanced shall be reached by means of hydraulic adjustment of collectors using suitable fittings in all the parallel connected rows of collector array. The maximum divergence of the heat flow rate

per unit collector area of each row shall not exceed 20 % of the nominal flow rate per unit collector area of the whole array as stated by the manufacturer.
The flow distribution balance could be achieved by means of suitable indicative flowmeters or other relevant method (e.g. check of temperature at the output of each row).
Check the documentation for the existence of the appropriate components and fittings.

5.2 Supporting frame

Requirements by EN 12977-1:
Manufacturer shall state the maximum possible loads for their metallic supporting frame, in accordance with EN 1993-1-1 and EN 1999-1-1.
For non-metallic supporting frames, the maximum acceptable load shall be stated.
This shall be mentioned in the documents for the installer.
Allowance of installing the system is depending on national requirements. Guidelines can be found in EN 1991-1-3 and EN 1991-1-4.

Discussion:
Information from the collector testing in accordance to §5.9 of EN 12975-2:2006 (negative pressure resistance test for the collector), considering the fixings between collector box and mounting system shall be taken into consideration if available.

SKM implementation:
Manufacturer shall state the maximum possible loads for their metallic supporting frame, in accordance with EN 1993-1-1 and EN 1999-1-1. Check the calculation proving the resistance of the frame to snow and wind loads in accordance with EN 1991-1-3 and EN 1991-1-4 where applicable.

For non-metallic supporting frames, the maximum acceptable load shall be stated. This shall be mentioned in the documents for the installer.

Allowance of installing the system is depending on national requirements. Guidelines can be found in EN 1991-1-3 and EN 1991-1-4.

5.3 Collector and other loops

Requirements by EN 12977-1:
Collector and other loops shall be able to withstand expansion/contraction due to thermal mechanical influences.

SKM implementation:
No physical test is required.
Check the installation as well as in the documentation for the installers if the manufacturer has taken into consideration, during the design of the system, all

the necessary precautions to withstand mechanical expansion/contraction of hydraulic parts by adopting appropriate hydraulic fittings.

5.4 Circulation pumps

Requirements by EN 12977-1:
See EN 809, EN 1151-1 and EN 12977-5.

SKM implementation:
See EN 809, EN 1151-1 and EN 12977-5.

5.5 Expansion vessels

Requirements by EN 12977-1:
For certain system designs, e.g. a drain-back system, a separate expansion vessel is not necessary, on condition that the integrated expansion facility is adequately designed to fulfil its task, in terms of volume, temperature and pressure resistance.
Each open system shall be provided with an expansion vessel or similar means, the volume of which shall be dimensioned so that it is capable of absorbing at least the entire expansion of the heat transfer medium between the lowest and the highest possible operating temperature. Each expansion vessel or alternative means shall be provided with a spill line and with a connection to atmosphere, which cannot be shut off.
There are no requirements for closed expansion vessels for the large solar systems. However, it is recommended that expansion devices for such systems are designed in order to take into account all potential thermal expansion.

Discussion:
Usually *large custom-built systems* are equipped with an open or closed expansion vessel, adequately designed to fulfil its task, in terms of volume, temperature and pressure resistance and designed in order to take into account all potential thermal expansion. For certain system designs, e.g. drain-back systems, a separate expansion vessel is not required.

If an open-vented expansion vessel is adopted it shall be provided with a connection to atmosphere, which cannot be shut off, and with a spill line.

If a closed expansion vessel is adopted it shall be dimensioned in such a way that even after an interruption of the power supply to the circulation pump in the collector loop just when solar irradiance is maximum, operation can be resumed automatically after power is available again and the absorber is filled again with liquid, i.e. vapour has re-condensed.

If open-vented water storage is adopted then it shall be designed in order to take into account all potential thermal expansion of the heat transfer fluid.

All expansion facility shall be checked out both by calculation and the hydraulic scheme in order to guaranty whether this is able to fulfil its task.

SKM implementation:
No physical test is required.
Check in the documentation for the installers if the manufacturer has taken into consideration, during the design of the system, all the necessary precautions to withstand thermal expansion/contraction of the heat transfer fluid. Check if the system is equipped with the appropriate means.
Check both by calculation and the hydraulic scheme to see whether the integrated expansion facility (open, close or other) is able to fulfil its task. Check the connection of the vessel to the atmosphere, the spill line and the expansion lines on the hydraulic scheme.

5.6 Heat exchangers

Requirements by EN 12977-1:
See EN 307.
If the system is intended to be used in areas with high water hardness and at temperatures above 60 °C, heat exchangers in contact with drinking water shall be designed so that scaling is prevented or there shall be a means for cleaning.
The reduction of the collector efficiency induced by the heat exchanger shall not exceed 10 % (absolute). If more than one heat exchanger is installed, this value shall also not be exceeded by the sum of reductions induced by each one of them. This criterion also applies if a load-side heat exchanger is part of the system.

SKM implementation:
Check in the documentation if the manufacturer has all the necessary certifications according to the requirements of the EN 307 Standard. Check the design of the heat exchanger(s) with respect to scaling or the availability of cleaning facilities.
Estimate the drop in system efficiency Δη induced by a heat exchanger in the collector loop by Equation:

$$\Delta\eta = (\eta_0 \; A_C \, a_1 / (UA)_{hx}) \times 100\ \%$$

(UA)hx is taken from the heat exchanger performance data sheet provided by the manufacturer and no further measurements are required.

For heat exchangers in other loops (e.g. a load side heat exchanger), the average temperature difference on the primary side Δϑ which is induced by the presence of the heat exchanger shall be estimated by calculation.

The drop in system efficiency $\Delta\eta$ induced by a heat exchanger in the collector loop may be estimated by Equation:

$$\Delta\eta = (a_1 \Delta\vartheta / G_{ref}) \times 100\ \%$$

where the reference solar irradiance Gref is set to 1 000 W/m2.
The reduction of the collector efficiency induced by the heat exchanger shall not exceed 10 % (absolute).

5.7 Water store(s)

Requirements by EN 12977-1:
There is no requirement on the stand-by heat loss rate capacity rate of stores of *large custom built systems*.

However, it is recommended to apply the Equation applied to the *small custom-built systems*: The stand-by heat loss capacity rate, (UA) of stores of custom built systems shall not exceed the value of 0,16 times the sqrt(total volume of store in liters, Vn, as stated by manufacturer).

$$UA = 0.16\sqrt{V_n}$$

Discussion:
EN 12977-2 does not require any test and does not report a calculation method.

The actual value of heat loss rate of stores of large systems could be obtained from the application of the method described in the §7.8 of the ISO 9459-2 Standard.

A short description of this method is presented below.

The test is performed in order to determine the heat loss coefficient of the store.
Test is performed overnight with no radiation. The water in the store of the system is heated to a uniform temperature above 60°C. Following this, the tank is left the whole night long for a period of at least 12 hours (cold period). In this period, there may be some early morning or late evening hours as long as during these hours the collector gets no irradiance. At the end of the cold period the water of the tank is circulated so that it reaches a uniform temperature. During the test, the ambient air temperature near the tank is measured every hour during the cold period. Moreover, the initial mean temperature of tank water t_i and the final mean temperature of tank water t_f are recorder. From these values, the average ambient air temperature during the cold period, $t_{as\ (av)}$ and the test duration Δt is found. The heat loss coefficient UA in [W/K] is then given by the following relation:

$$UA = \frac{\rho_w c_{pw} V_n}{\Delta t} \ln\left[\frac{t_i - t_{as\ (av)}}{t_f - t_{as\ (av)}}\right]$$

Where V_n is the store volume in lt .

SKM implementation:
No requirements for testing.

It is recommended the Equation (1) applied to check if the stand-by heat loss capacity rate of the store is satisfactory.

Determination the heat loss capacity rate can be performed by calculation or test (the method described in the §7.8 of the ISO 9459-2 could be used).

5.8 Pipework

Requirements by EN 12977-1:
The pipe length of the system shall be as short as possible. The pipes and fittings shall be selected from materials that are compatible with the components included in each loop, according to the fluid of the loop as specified in ISO/TR 10217.

The design of the system and the used materials shall be such that there is no possibility of clogging and lime deposit in its circuits which would significantly deteriorate the system performance in the lifetime.

The pipework for drinking water shall comply with the requirements specified in EN 806-1 and EN 806-2.

The materials for pipes and fittings shall be suitable to withstand the maximum operating temperature (stagnation conditions) and pressure. The pipework shall withstand thermal expansion without any damage or detrimental deformation.

Venting of the system (removal of unwanted gasses) shall be possible. No automatic vents shall be placed in parts of the collector loop where vapour can occur (e.g. the top of the collector array), except where a manual valve is placed between the pipe and the automatic vent, this valve being closed during normal operation of the system, or except a warning is added to the operating instructions, indicating that the system does not automatically resume operation after stagnation conditions (see also 6.4.3).

SKM implementation:
Design plan and system documentation in respect of design and material of pipes and fittings shall be checked and the pipework in the collector loop the compliance with ISO/TR 10217 shall be ensured.

5.9 Thermal Insulation

Requirements by EN 12977-1:
The thermal insulation of all connecting pipes and other components of the system shall comply with the requirements given in EN 12828.

All the hydraulic collector loops shall be insulated without any gaps between the components. Thermal bridges, e.g. incorrectly installed mounting clamps shall be avoided. Design plans and system documentation shall be checked.

The thermal insulation of the pipework shall be from materials which are resistant to the maximum temperature of the circuit and deformation and which remain operative. If the insulation is installed outside, it shall be protected against (or resistant to) solar radiation, environmental conditions, ozone and any mechanical impact/deformation.

Insulated pipes for underground installation shall comply with EN 253.

SKM implementation:
Check the design plans and system documentation for compliance to the requirements.

5.10 Control equipment

Requirements by EN 12977-1:
See EN 12977-5

SKM implementation:
Testings according to the EN 12977-5

6. Requirements on Safety equipment and indicators

6.1 Safety valves

Requirements by EN 12977-1:
Each section of the collector array which can be shut off shall be fitted with at least one suitable safety valve of suitable dimension. The safety valve shall resist the temperature conditions which it is exposed to, especially the highest temperature that can occur. The safety valve shall resist the heat transfer medium.
The safety valve shall be dimensioned such that it can release the highest flow of hot water or steam that can occur. The dimension of the safety valve(s) shall be proved by suitable means.

Discussion:
Before each safety valve it is recommended to place a cut-off valve in order to facilitate maintenance and / or testing work.

SKM implementation:
No physical test is required.
Design plan and the system documentation shall be checked in order to verify that each collector or each section of collector array which can be shut off is fitted with at least one suitable safety valve and check whether the size of the safety valve is correct. Specification of the safety valves, whether the materials fulfill the requirements given in EN 12977-1:2011, §6.5.1.

Before each safety valve it is recommended to place a cut-off valve in order to facilitate maintenance and / or testing work.

For testing the system behavior after release of one or more safety valves according to the requirements given in EN 12977-1:2011, 6.5.1, the electric and hydraulic schemes or any other part of the documentation according to EN 12977-1:2011, 6.8.3 shall be checked.

6.2 Safety lines and expansion lines

<u>Requirements by EN 12977-1:</u>
The safety line shall not be capable of being shut off or deformed in such a way that would reduce its discharge capacity below that necessary to maintain system pressures below the stated maximum for hot water or steam escaping from the safety lines.
The safety line and expansion line shall be dimensioned such, that for the highest flow rate of hot water or steam that can occur, the maximum allowed pressure is not exceeded at any place in the collector loop, taking also into consideration the pressure drop in these lines. The dimensions of the safety line and expansion line shall be proved by calculation or experimental means.
The junction of the expansion line and the safety line shall be set out in such a way that any accumulations of dirt, scale or similar impurities are avoided.

<u>SKM implementation:</u>
No physical test is required.
Check the hydraulic scheme and system documentation to verify that safety and expansion lines cannot be shut off and they are connected and laid in such a way that any accumulation of dirt, scale or similar impurities is avoided.
Check the internal diameter of the safety and the expansion line with respect to the requirements given in EN 12977-1:2012, 6.4.2.

6.3 Blow-off lines

<u>Requirements by EN 12977-1:</u>
The blow-off lines shall be laid in such a way that they cannot freeze up and that no water can accumulate within these lines. The orifices of the blow-off lines shall be arranged in such a way that any steam or heat transfer medium issuing from the safety valves does not cause any risk for life, materials or environment.

<u>SKM implementation:</u>
System documentation shall be checked in order to verify compliance with the above requirements.

6.4 Store isolation valve

Requirements by EN 12977-1:
Stores of large custom built systems with a volume of more than 20 m^3 shall be fitted with isolation valves or other suitable devices to stop unintentional outflow of the store contents in cases of system failure.

Discussion:
All the connections of the store shall where relevant be equipped with isolation valves in order to facilitate maintenance also.

SKM implementation:
Check the hydraulic scheme and system documentation to verify the existence of shut-off valves or other suitable devices to stop unintentional outflow of the store contents in cases of system failure, in accordance with EN 12977-1:2012, 6.5.4.

6.5 Indicators

Requirements by EN 12977-1:
The system shall be fitted with an indication method for confirming the collector loop circulation. This could be a flow rate indicator: two thermometers which indicate the actual flow and return temperatures of the collector loop or another appropriate method.

For the indication of the system pressure in case of filled systems, collector loops shall be fitted with a pressure gauge at a clearly visible spot of the installed system. The allowable working range of the system pressure shall be indicated.

For large custom built systems, the loops shall be equipped with a heat meter in order to balance each collector loop and facilitate the system performance.

Discussion: .....
At least one thermometer at the inlet and outlet of each collector loop as well as before and after the heat exchanger is recommended in order to facilitate balance and regulation of all loops. The presence of the heat meter is preferable.

SKM implementation:
Check the hydraulic scheme and system documentation in respect of the position and installation of the recommended indicators, thermometers, pressure gauges and heat meters.

7. Requirements on Installation

7.1 Roof tightness

Requirements by EN 12977-1:
If collectors are installed on the roofs of buildings, the weather tightness of the roof cover shall not be impaired.

SKM implementation:
If collectors of *large custom-built systems* are installed on the roofs of buildings (usually industrial buildings), the weather tightness of the roof cover shall not be impaired.
Check the design plans and the system documentation to see whether the leak tightness of the roof may be affected by the installation of the collector.

7.2 Lightning

Requirements by EN 12977-1:
The system shall meet the requirements given in EN 62305-1.

SKM implementation:
Check the design plans and the system documentation to see if the manufacturer, during the design phase, has taken into consideration the requirements of the EN 62305-1.

7.3 Snow and wind loads

Requirements by EN 12977-1:
All parts of the system installed outdoors (collector array), shall be resistant to snow and wind loads according to EN 1991-1-3 and EN 1991-1-4. The manufacturer shall state the maximum values for s_k (snow load) and v_m (mean wind velocity) according to EN 1991-1-3 and EN 1991-1-4. The system may only be installed at locations, where the values of s_k and v_m determined according to EN 1991-1-3 and EN 1991-1-4 are lower than the maximum values stated by the manufacturer. This shall be mentioned in the documents for the installer.

SKM implementation:
Check the system documentation to see if the manufacturer, during the design phase, has taken into consideration the requirements of EN 1991-1-3 and EN 1991-1-4 Standards (where applicable). Moreover, check whether the documents for the installer comply with EN 12977-1:2012, 6.6.3

8. Requirements on Initial Operation and Commissioning

Requirements by EN 12977-1:

Before initial operation of a *large custom built system*, it shall be ensured that:

- the installed system complies with the requirements of the Standard;
- corresponding fittings are adjusted and the adjustments are recorded;
- the supervisor of the system, if there is one, is instructed.

Large systems shall be tested as specified in EN 12977-2 and monitored as specified in EN 12977-2

Discussion:

Even if the procedures described in EN 12977-2 are optional it is recommended to be taken into consideration for *large custom-built systems.* (this is, of course, is to be diswcussed. There might be two levels of certification: On with and one without testing/monitoring.

SKM implementation:

Before initial operation:

- check whether the system layout and components are as described in the documentation;
- check the record of the adjustments for the corresponding fittings. For each fitting a recorded adjustment shall exist;
- if there is a supervisor of the system, ensure that he has been sufficiently instructed.

The procedure for short-term system testing referred to in EN 12977-1:2012, 6.7 (only if needed or required) is given in Annex C. The procedure for long-term system monitoring referred to in EN 12977-1:2012, 6.7 (only if needed or required) is given in Annex D. (see §10).

9. Requirements on Documentation

Requirements by EN 12977-1:

The manufacturer or official supplier shall deliver documents for assembly, installation and commissioning (for the installer) and documents for operation (for the user). These documents shall be written in the official language(s) of the country of sale. These documents shall include all instructions necessary for assembly and operation, including maintenance, and draw attention to further requirements and technical rules. In particular, guidelines for check and maintenance of the collector loop fluid shall be given.

Full documentation of the system according to §6.8.4 of the EN 12977-1 shall be provided.

SKM implementation:

Check all documents, as to whether they fulfil the requirements given in EN 12977-1:2012, 6.8.4.

10. Requirements for system performance

Requirements by EN 12977-1:
There are no requirements for *large custom-built systems*. However, if monitoring of the system is considered, it is recommended to use the methods for large systems described in EN 12977-2.

Discussion:
According to the current version of the Solar Keymark Scheme Rules, only "*factory made systems*" tested according to EN 12976 could have Solar Keymark certification, giving to those a benefit and a marketing advantage.

From the other hand, large solar thermal systems constitute a preferential field in broadening the range of solar energy applications and the reliable assessment of the qualitative features, based on the energy performance of those systems, constitute an important parameter in market penetration, mainly in hotels, industries and residential buildings. The investors are very hesitant to proceed in financing installations of this kind, due to the lack of the necessary assurances regarding the expected outcome. In the meantime there is a growing tendency of the authorities to require system certification which in combination with the subsidization is used as a tool in promoting and facilitating the market penetration of high quality and innovative products.

As *large custom built systems* are by definition unique systems, only general procedures on how to check and supervise them may be given. In the annexes C and D of the EN 12977-2 Standard several possible levels of analysis are included.

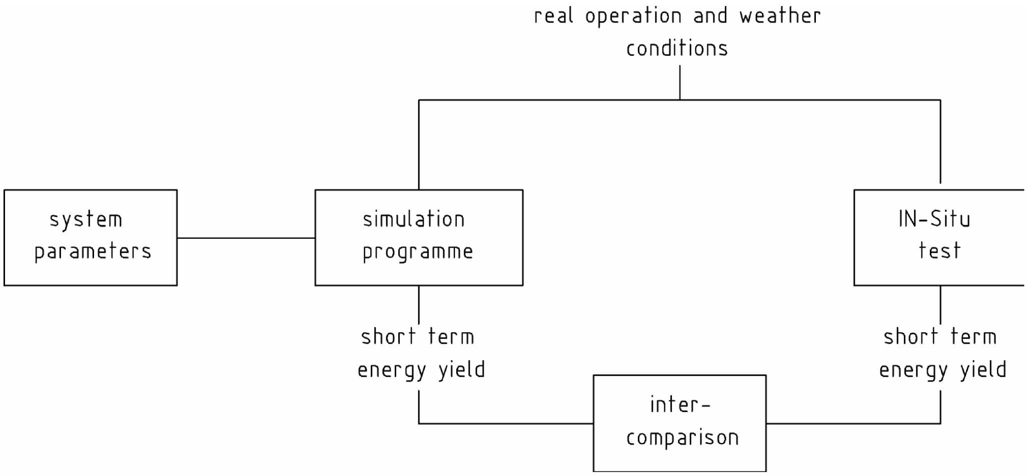
Note: For the *large custom-made solar thermal systems* the concept of "system family" is not applicable and the certification is valid only for the specific configuration.

Following, the two methods proposed for the short-term system testings as well as the long-term monitoring are reported.

a) *Short-term system tests*

The objective of the two short-term system tests presented in **Annex C** is the characterization of system performance and/or the estimation of the ability of the system to deliver the energy claimed by the designer. In principle, two approaches for short-term system testing are referred to in this European Standard:

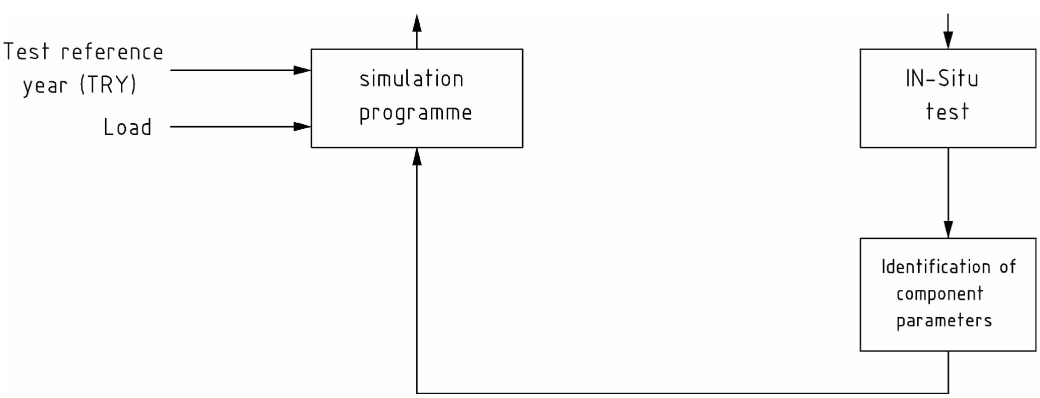
a1) Simplified check of short-term system performance, carried out by intercomparison of the measured thermal solar system heat gain with the one predicted by simulation, using the actual weather and operating conditions as measured during the short-term test;



a2) Short-term test for long-term system performance prediction. The performance of the most relevant components of the solar heating system is measured for a certain time period while the system is in normal operation.

More detailed measurements encompass

i) Energy gain of collector array(s) and
ii) Energy balance over storage vessel(s).



Intercomparison of the observed and simulated energy quantities provides the indirect validation of collector and storage design parameters. The measured data within the collector array are also used for direct identification of the collector array parameters. As far the component parameters are verified, the long-term prediction of the system gain as well as the detection of possible sources of system malfunctioning are possible.

b) Long-term monitoring

Annex D of EN 12977-2 describes a procedure for long-term monitoring as a part of the supervision of a large custom built solar heating system. The objectives of supervision may be:

1) the early recognition of possible failures of system components, in order to get the maximum benefit from the initial solar investment as well as to minimize the consumption of non-solar energy and the resulting environmental impact,

2) the measurement of system performance (solar gains or other system indicators), if requested by a contractual clause, e.g. guaranteed results.

The long-term monitoring in Annex D is limited to the solar energy specific aspects, especially to the determination of the solar contribution to the total heat load. Instrumentation used in the long-term monitoring should be an integrating part of the system, a part included from the very beginning of the design process. If adequately foreseen, it may also be used for system adjustment at start time.

<u>SKM implementation:</u>

There are three candidate scenarios:

a) If the short-term system testing is adopted, then one of the two methods proposed by the EN12977-2 Standard in Annex C have to be followed:

   a1) Simplified check of short-term system performance.

   a2) Short-term test for long-term system performance prediction.

   Simulation methodologies based on: the Dynamic Input-Output [1], the f-chart [2] and the Component Testing - System Simulation (CTSS) (TRNSYS program), taken from the relevant literature, could be investigated and evaluated, by taking into consideration the specific characteristics of the method for each application.

b) If the long term monitoring of the *large custom-built system* after commissioning is selected, then Annex D of the EN12977-2 has to be followed.

The certification could be carried out based on the comparison between the calculated and / or predicted values of the long term performance prediction of the system. Aim of the certification should be therefore to include information regarding the long term performance prediction (yearly energy output).

11. References

[1] Belessiotis, V.G., Mathioulakis, E., Papanicolaou, E., "Theoretical formulation and experimental validation of the input–output modelling approach for large solar thermal systems", *Solar Energy* 84 (2010) 245–255

[2] Duffie, J.A., Beckman, W.A., (2006). Solar Engineering of Thermal Processes, third ed. Wiley.

[3] ISO 9459-5, Solar heating - Domestic water heating systems - Part 5: System performance characterization by means of whole-system tests and computer simulation.

[4] EN 12977-1, Thermal solar systems and components - Custom built systems - Part 1: General requirements for solar water heaters and combisystems

[5] EN 12977-2, Thermal solar systems and components - Custom built systems - Part 2: Test methods for solar water heaters and combisystems.

[6] EN 12977-3, Thermal solar systems and components - Custom built systems - Part 3: Performance test methods for solar water heater stores

[7] EN 12977-4, Thermal solar systems and components - Custom built systems - Part 4: Performance test methods for solar combistores

[8] EN 12976-2, Thermal solar systems and components - Factory made systems - Part 2: Test methods

[9] EN 15316-4-3: Heating systems in buildings – Method for calculation of system energy requirements and system efficiencies – Part 4-3: Heat generation systems, thermal solar systems.