# ANNEX D. SOLAR KEYMARK SYSTEM FAMILIES

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## D.1 System family, system subtype

A system family is a family of different system configurations / sizes of the same system subtype.

In D.2 the requirements for considering systems as being of the same subtype are given.

## D.2 Requirements for grouping different system configurations into one system family

*In the following the indices max and min indicates maximum and minimum values of the parameter for all systems in the family.*

Values to be used to check the below requirements are taken from:

* Collector parameters: EN 12975 test report
* Other values: Manufacturers declaration; check of values shall be performed by test lab based on drawings and other material/information provided by manufacturer.
* Hydraulics:
	+ same principle layout of solar and load loops
* Heat transfer fluid :
	+ same type of liquid (same brand and same water mixing percent - or declaration from manufacturer that the fluid is equivalent)
* Heat exchanger(s) (if any):
	+ same type of heat exchanger (mantel / spiral / external)
	+ heat transfer coefficient of heat exchanger shall - for each system configuration - be known/declared and large enough to fulfil:
		- $(UA)\_{hx}>10 K\_{50}η\_{0a}( A\_{a} a\_{c}+U\_{loop,total})$ (determination of (UA)hx, see D.4.2.1)

where:

* + - (UA)hx: Heat transfer coefficient of the solar loop heat exchanger, W/K
		- K50 : Collector incidence angle modifier at 50°, -
		- η0a : Collector zero heat loss efficiency coefficient, -
		- Aa : Collector aperture area of collector array, m²
		- ac: Collector heat loss coefficient at Tm - Ta = 40 K, W/(K m²);

ac = a1a + a2a \* 40

* + - Ta: Air temperature, °C,
		- Tm: Collector mean temperature, °C
		- a1a : 1st order collector loss heat coefficient based on aperture area, W/(K m²)
		- a2a : 2nd order collector heat loss coefficient based on aperture area, W/(K² m²)
		- Uloop,total:  Total heat transfer coefficient of solar loop; Uinsu + Uun-insu, W/K
		- Uun-insu: Heat loss coefficient of un-insulated part of collector loop piping, W/K
		- Uinsu: Heat loss coefficient of insulated part of collector loop piping, W/K
* Tank(s):
	+ same brand - or declaration from manufacturer that the brands of the tanks are equivalent)
	+ same tank orientation (vertical or horizontal)
	+ same tank material
	+ same inside coating
	+ requirements on heat losses:
		- same insulation material (same material specifications)
		- restricted tank heat loss coefficient for tanks with integrated supplementary heating:
			* UAtank < 0.32 \* (Vtot)½
		- restricted variation from tank to tank of average thickness of tank insulation:
			* (tinsu,tank,max - tinsu,tank,min)/tinsu,tank,min) ≤ 25% (~ tinsu,tank,max ≤ 1.25\* tinsu,tank,min)
	+ or :
		- *In case test results are available for heat loss according to EN 12977-3 or EN 12897, the requirements on insulation can be expressed as : restricted variation of heat loss coefficient(Wh/l/K/day): maximum 40 % relative variation allowed.*
	+ similar relative position of solar heat exchanger; variation to be accepted:
		- ± 20 % variation (relative to average positions) allowed in relative positions of lower and higher points of heat exchanger (positions taken relative to tank height)
	+ restricted variation in total tank volume,:
		- (Vtot,max - Vtot,min)/Vtot,min ≤ 200% (~ Vtot,max ≤ 3\* Vtot,min)
	+ restricted variation in relative supplementary heated tank volume, Vaux/Vtot (the indices max and min indicates maximum and minimum values):
		- ((Vaux/Vtot),max - (Vaux/Vtot),min)/(Vaux/Vtot),min ≤ 25% (~(Vaux/Vtot),max ≤ 1.25\* (Vaux/Vtot),min)
* Collectors:
	+ shall have Keymark
	+ shall same Keymark licence no. (i.e. same collector subtype for all systems)
	+ limitation on collector heat loss coefficient, ac:
		- ac < 8 W/(K m²) (to limit dependence on wind); ac = a1a + a2a\*40
	+ restricted variation in collector aperture area of collector array, Aa:
		- (Aa,max - Aa,min)/Aa,min ≤ 300% (~ Aa,max ≤ 4\* Aa,min)
* Pipes/piping:
	+ see annex B of EN 12976-2 and tables B2 and B3 for pumped systems and thermosiphons respectively.
	+ guidelines for calculating piping losses:

Heat loss coefficient of un-insulated pipe surface (and other un-insulated surfaces) can be determined as:

* Uun-insu = 15 \* Asurface-un-insu [W/(K)]

Heat loss coefficient of insulated pipe surface (and other insulated surfaces) can be determined as:

* Pipes: Uinsu-pipe = 2\*pi\*lambdainsu\*Lpipe /ln((dpipe +2tinsu,pipe)/dpipe), [W/K]
* Plane surfaces: Uinsu-plane =Aplane \*lambdainsu/tinsu,plane, [W/K]

*Is lambda (heat conductivity of insulation) not known, use 0.04 W/(K\*m)*

* + total collector loop piping heat loss coefficient, Uloop,total (total heat loss coefficient from pipes, etc. between collectors and store/heat exchanger) shall be less than 30 % of the total collector heat loss coefficient:
* $U\_{loop,total}<0.3 A\_{a} a\_{c}$
* Controller(s) (if any):
	+ same brand, type and settings of controller(s)
	+ same brand, type and same/similar location of sensors; restriction on relative location(s) of sensor(s) in the tank:
		- ± 10 % variation (relative to average positions) allowed in positions relative to tank height
	+ overheating protection / temperature limiting functions:
		- same principle(s)/functions for all system configurations
* Pump(s) (if any)
	+ same specifications with respect to operating conditions (temperatures, pressure, fluid, …). Nominal power for all pumps used in the family shall be reported. PNOM for a system with a given collector aperture area shall be smaller than or equal to PNOM for a system with a bigger aperture collector area.

## D.3 Testing requirements

The “medium system configuration” shall be tested according to all requirements in EN 12976 - except for “Over temperature protection” (EN 12976-2 section 5.2).

The “medium system configuration” is the configuration having the ratio of collector aperture area to total store volume closest to the average value of this ratio calculated for all configurations in the family. If several configurations are equally close to the average, the configuration with the highest ratio of aperture area to volume shall be chosen.

Testing the over temperature protection and safety (EN 12976-2 5.2) shall be carried out on the configuration having the highest ratio of collector aperture area to total store volume.

*Note D.3.1: Normally two system configurations have to be sampled for (parallel) testing, but in some cases one configuration could at the same time be both the “medium system configuration” and the configuration with the highest ratio of collector aperture area to total store volume. In such case it is possible to sample only one configuration and perform all testing on this configuration.*

*Note D.3.2: Collector aperture area is defined in EN 12975; total store volumes is declared by manufacturer for all tank sizes in the system family.*

## D.4 Methods for determination of performance of system configurations which are not tested

The performance of the system configurations which are not tested is determined using one of two calculation methods:

* Method I: Based on EN 15316-4-3 - in the following named “Method I (f-chart)”
* Method II: Based on EN 12976-2 / ISO 9459-5 in the following named “Method II (DST)”

The method to use depends on the test method used in D.3 and whether the system is a forced circulated system or a thermo-siphon system - see table below.

|  |  |  |
| --- | --- | --- |
| Test method applied: | ISO 9459-2 (CSTG) | ISO 9459-5 (DST) |
| Solar only / int. back-up: | Solar only | Solar only | Int. back-up |
| Forced Circ. / Thermo-Siphon: | FC | TS | FC | TS | FC | TS |
| **Method I (f-chart) valid:** | √ | √ | √ |   | √ |   |
| **Method II (DST) valid:** |   |   | √ | √ | √ | √ |

*Table D.4.1*

*Applicable extrapolation method depending on system type and test method*

It is seen from the table that:

* Method I (f-chart) is applicable for forced circulated systems and thermosyphon systems tested as solar only/pre-heat system.
* Method II (DST) is only applicable in connection with the ISO 9459-5 (DST) performance test method

The method used for performance calculation shall be specified when reporting the results.

The two methods are described in the following.

### D.4.1 Method I (f-chart)

If the system is a pumped system or thermosyphon system tested as solar only/pre-heat system Method I (f-chart) can be used. This method is based on the method B in the EN 15316-4-3 and is illustrated in the figure below:

Test reference system according to EN 12976-2 using ISO 9459-5 DST or ISO 9459-2 CSTG to obtain the solar heat delivered Ql,ref and the heat demand Qd,ref for 4 locations and several loads according to the Table B.1 in the appendix B of EN 12976-2

Calculation of collector loop efficiency factor and solar heat exchanger heat transfer value for the reference system corresponding to Ql,ref 🡪 using EN 15316-4-3 – Method B

Calculation of Qd,ref,fit using fitted collector loop efficiency factor.

Check OK? (1)

Extrapolation of results for other systems of the family is not possible.

No

Yes

Calculation of collector loop efficiency factor and solar heat exchanger heat transfer value for other systems of the family

Calculation of the heat loss coefficient of the collector loop piping for each system

Calculation of Ql and Qd for each system of the family

Area of solar heat exchanger and collector aperture area of other systems of the family

Characteristics of each system:

* collector aperture area
* store volume
* backup volume

Annual performances of whole system family

*Fig. D.4.1.1 Principle of Method I (f-chart)*

1. The check is based on the calculation of the deviation for all locations and loads according to:

(%)

If δ≤±15% the extrapolation can proceed.

Method I is organised in three stages:

1. **Pre-processing of test data:**

Inputs for the method I are Qsol,out and Qsol,us as defined in the EN15316-4-3, method B. Two cases have to be separated:

Preheat systems:

Qsol,out = QL / 3.6 [kWh/year]

Qsol,us = QD / 3.6 [kWh/year]

Where:

QD is heat demand (result from EN12976) [MJ/year]

QL is heat delivered by the solar heating system (according to EN12976) [MJ/year]

Solar plus supplementary systems

 Qsol,out = (QD + Qst,ls,aux – Qaux,net) / 3.6 [kWh/year]

Qsol,us = QD / 3.6 [kWh/year]

 Where:

 Qst,ls,aux is heat losses of the store part heated by the back-up heater [MJ/year]

 Qaux,net is net auxiliary energy demand [MJ/year]

Qst,ls,aux is calculated using the formula given in the EN 15316-4-3 § 6.3.5 using the control strategy adopted for the system, the surrounding air temperature, the set temperature, the fraction of the store volume heated by the back-up heater and the heat loss coefficient of the store. This coefficient is calculated using the following formula:



Where:

* λiso is the heat transfer coefficient of the insulation material [W/m.K]
* Asto is the outside area of the auxiliary part of the store [m²]
* diso is the thickness of the insulation material [m]

If these three parameters are not known, the following formula can be applied:



Where Vbu is the volume of the auxiliary part of the store [L]

1. **Processing:**

The collector loop efficiency factor ηloop for the reference system is fitted using the annual outputs resulting from the EN 12976 test for each location and each load (Qsol,out calculated as described above).

Using the fitted collector loop efficiency factor ηloop the Qsol, out is calculated according to EN 15316-4-3 and compared with the annual energy output measured. The deviation between the measured value and the calculated values, as defined in (1), shall be lower than ±15%. If this is verified for all reference locations and load volumes, the extrapolation procedure can proceed. If the differences are higher than ±15% the extrapolation is not possible.

From these fitted factors ηloop of the reference system, an apparent solar heat exchanger heat transfer value (Ust)hx is calculated for each location and load using the calculation formula given in the appendix B.2 1 of EN 15316-4-3:



 (1)

 With:



Where:

* A is the total collector aperture area [m²]
* (Ust)hx is the apparent solar heat exchanger heat transfer value for the actual location and load [W/K]
* a1 is the1st order collector heat loss coefficient based on aperture area, [W/(K.m²)]
* η0 is the optical efficiency based on collector aperture area

The (Ust)hx coefficient for each system of the family is determined using the following formula :



Where:

* (Ust)hx,x is the solar heat exchanger heat transfer value of the actual system [W/K]
* (Ust)hx,ref is the solar heat exchanger heat transfer value of the reference system [W/K]
* Ahx,x is the area of the heat exchanger of the actual system [m²]
* Ahx,ref is the area of the heat exchanger of the reference system [m²]

If the area of the heat exchanger of the actual system is unknown, its (Ust)hx coefficient is considered equal to the (Ust)hx of the reference system.

The collector loop efficiency factors ηloop can then be calculated for each other system of the family for each location and load using its collector aperture area with the calculation formula (1).



 (2)

Where:

* Ax is the collector aperture area of the actual system [m²]

This collector loop efficiency factor is one of the elements used to calculate the solar heat delivered by the actual system. For each system, the collector aperture area, the store volume, the backup volume and the heat loss coefficient of the collector loop pipes have also to be known to carry out this calculation. The first three of these elements are provided by manufacturers.

The collector loop pipe losses can be calculated using:



Where:

* Uloop,p is the heat loss coefficient of the collector loop piping [W/K]
* Uinsu is the heat loss coefficient for insulated part of collector loop piping [W/K]
* Uun-insu is the heat loss coefficient for the un-insulated part of collector loop piping [W/K]

If no qualified values are available for the coefficients Uinsu and Uun-insu, Uloop,p can also be calculated using the following formula:



Finally, by using the ηloop,x ,the collector aperture area, the store volume, the backup volume and the heat loss coefficient of the collector loop pipes, the solar heat delivered by each system of a family Qsol,out,x can be calculated with e.g. the software SOLEN[[1]](#footnote-1).

All the equations and mathematical models used to calculate this solar heat delivered by each SDHW system of a family are written on the EN 15316-4-3 – Method B and examples of implementation of this method B are available on the appendix A of this standard.

1. **After processing**

The output of EN15316-4-3, method B is translated for each system of a family in terms of EN12976 according to:

Preheat systems:

QL= Qsol,out,x x 3.6 [MJ/year]

QD = Qsol,us,x x 3.6 [MJ/year]

Solar plus supplementary systems:

 Qaux,net, = (QD + Qst,ls,aux,x – Qsol,out,x) x 3.6 [MJ/year]

QD = Qsol,us,x x 3.6 [MJ/year]

Finally, for preheat and solar plus supplementary systems, the auxiliary energy consumption by pumps Qpar has also to be calculated for each system of the family:



Where:

* Qpar is the auxiliary energy consumption by pumps [MJ/year]
* Paux is the total nominal input power of pumps [W]
* taux is the annual pump operation time, fixed to 2000 h

### D.4.2 Method II (DST)

When the system performance test (in D.3) is done according to ISO 9459-5 (DST), the Method II (DST) can be used for both pumped systems and thermo-siphon systems. This method is based on the ISO 9459-5 procedure for performance calculation, which is one of the two methods for performance calculation already used in the EN 12976. The principle of the method is illustrated in the figure below.



*Fig. D.4.2.1 Principle of Method II (DST)*

The reference system is chosen and tested (see D.3). Two sets of system parameters are identified:

* “Free” reference system parameters - these are the parameters determined according to EN 12976 / ISO 9459-5.
* “Fixed” reference system parameters. These parameters are determined **fixing the collector parameters (AC\* and uC\*)** according to D.4.2.1 and identifying the rest of the system parameters using the same test data as used for determination of the “free” system parameters.

Next phase is a comparison of the annual performances determined using the two sets of system parameters.

**If the deviation for any location/load is higher than 15%, reliable performance prediction for other configurations is not likely to be obtained.** The information/data used should be checked as well as the operation of the tested system.

If the deviation for any location/load is lower than 15%, proceed to next phase of the method.

In this phase the system parameters for all system configurations in the system family are determined:

* The collector parameters (AC\* and uC\*) are determined according to D.4.2.1 for all configurations (beware that these parameters also depends on heat exchanger and pipe losses - and number of collectors).
* The store heat loss parameter (Us) is determined as:
	+ Us,x = Us,ref,fix \* Ax,surface/Aref,surface
* The store heat capacity parameter (Cs) is determined as:
	+ Cs,x = Cs,ref,fix \* Vx/Vref
* The parameter for back-up volume (fAUX) is in all cases set to the value of fAUX,fix already determined using the fixed collector parameters for the reference system
* The parameters for stratification (DL and SL) are in all cases set to the values already determined using the fixed collector parameters for the reference system
* The parameter for load side heat exchanger (RL) is determined as:
	+ RL,x = RL,ref,fix \* Alshx,x/Alshx,ref
* The parameter uv is not taken into account

where:

* Us,x : Store heat loss parameter to be determined for the actual configuration
* Us,ref,fix : Store heat loss parameter determined for the reference system using fixed collector parameters
* Ax,surface: Surface area of store in the actual configuration
* Aref,surface : Surface area of store in the reference configuration
* Cs,x : Store heat capacity parameter to be determined for the actual configuration
* Cs,ref,fix: Store heat capacity parameter determined for the reference system using fixed collector parameters
* Vx : Store volume in the actual configuration
* Vref : Store volume in the refernce configuration
* RL,x : Load side heat exchanger parameter to be determined for the actual configuration
* RL,ref,fix: Load side heat exchanger parameter determined for the reference system using fixed collector parameters
* Alshx,x: Surface area of load side heat exchanger in the actual configuration
* Alshx,ref: Surface area of load side heat exchanger in the reference configuration

Now with the system parameters determined, the annual performances of all system configurations, locations and loads can be done using the LTP part of the DST software [InSitu Scientific Software, Dynamic testing Program].

#### D.4.2.1 Calculation of “Fixed” collector parameters AC\* and uC\*

When doing the extrapolation calculations, fixed values for the parameters AC\* and uC\* are used in the result file DFR and DST-LTP program. The way to calculate these fixed values is shown in the following.

##### D. 4.2.1.1 Calculation of AC\*

In ISO 9459-5 AC\* is defined as:

* AC\* = FR\* \* (τα) \* AC

where:

* AC: Collector aperture area of collector array in m2
* FR\*: Heat removal factor of the collector loop
* (τα): Effective transmission-absorbtance product

Expressing AC\* in an approximate way in terms of collector test results related to EN 12975 and the heat exchanger factor F’’’:

* AC\* = F’’’\*η0a\* K50° \*Aa

where:

* Aa: Total collector aperture area in m²
* η0a : Optical efficiency based on aperture area
* K50° : Incidence angle modifier at 50°

The heat exchanger factor F’’’ is defined in the following:

* $F^{'''}= 1- ∆η\_{hx}$
* $∆η\_{hx}= \frac{η\_{0a} K\_{50°}(A\_{a} a\_{c}+ U\_{loop,total})}{(UA)\_{hx}}$
* Uloop,total = Uinsu + Uun-insu

where

* ac = a1a + a2a\*40; collector heat loss coefficient at Tm - Ta = 40 K, W/(K m²), Ta: air temperature, °C; Tm: collector mean temperature, °C.
* a1a : 1st order collector heat loss coefficient based on aperture area, W/(K m²)
* a2a : 2nd order collector heat loss coefficient based on aperture area, W/(K² m²)
* η0a : Collector zero loss efficiency based on aperture area
* K50° : Incidence angle modifier at 50° incident angle
* Aa : Collector aperture area, m²
* (UA)hx = Uhx \* Ahx; heat transfer coefficient of the heat exchanger, W/K
* Uhx : Heat transfer coefficient per m² of the heat exchanger, W/(K m²)
* Ahx : Total surface area of heat exchanger, m²
* Uloop,total : heat loss coefficient of the collector loop piping, W/K
* Uinsu : heat loss coefficient for insulated part of collector loop piping, W/K
* Uun-insu : heat loss coefficient for the un-insulated part of collector loop piping, W/K

For external heat exchanger actual value of (UA)hx is used for the temperature set:

* Primary loop 25°C, 35°C (collector loop)
* Secondary loop 15°C, 25°C (tank loop)

For tanks with internal heat exchangers a value of 200 W/K per m² heat exchanger surface (average of inner and outer surface) is chosen for Uhx if no qualified measurements (e.g. from EN 12977-3 test) are available for the (UA)hx for the heat exchanger. The test value to be used should comply with the conditions given in CEN/TS 12977-2 (6.3.6): “*(UA)hx to be chosen for store temperatures of 20°C, average temperature difference 10 K and a flow rate similar to the one used for the determination of the collector parameters*” (flow rate corresponding to the minimum number of collector modules applied to the tank within the system family).

Note: The value for Uhx : 200 W/(K m²) is based on test of 23 tanks with internal heat exchangers (tests performed at Danish Technological Institute).

##### D.4.2.1.2 Calculation of uC\*

In ISO 9459-5 AC\* is defined as:

* $u\_{C}^{\*}=\frac{ a\_{total}}{η\_{0a} K\_{50°} }$ , W/(K m²)

where:

* atotal: Specific heat loss coefficient of the collector loop **including collector(s)**, W/(K m²)
* η0a : Collector zero loss efficiency based on aperture area
* K50° : Incidence angle modifier at 50° incident angle

Expressing uC\* in an approximate way in terms of collector test results related to EN 12975:

* $u\_{C}^{\*}=\frac{ a\_{c}+ U\_{loop,total}/A\_{a}}{η\_{0a} K\_{50°} } $ ,W/(K m²)

including also heat loss coefficients for collector piping, where:

* ac = a1a + a2a\*40 (heat loss coefficient at dT = 40 K), W/(K m²)
* a1a :1st order collector heat loss coefficient based on aperture area, W/(K m²)
* a2a :2nd order collector heat loss coefficient based on aperture area, W/(K² m²)
* Aa : Collector aperture area, m²
* Uloop,total is heat loss coefficient of the collector loop piping, W/K
* Uinsu is heat loss coefficient for insulated part of collector loop piping, W/K
* Uun-insu is loss coefficient for the un-insulated part of collector loop piping, W/K

**D.5 Integrated collector storage system families**

**D.5.1 General**

ICS (Integral collector-storage system) is defined as a solar heating system in which the solar collector also functions as a heat(water) storage device. Similar ICS systems as defined in chapter 5.2 can be grouped into a family using the procedures described in this section. All ICS system of a family shall have the ratio of aperture area (m2) to volume (litres) less than 0.2.

The medium system of the family is defined according to D.3. If the variation of the ratio of volume to aperture area δ is below or equal to 7% ([≤](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=10&cad=rja&uact=8&ved=0ahUKEwilnrXRm7rbAhXJe8AKHTvRDPcQFghdMAk&url=http%3A%2F%2Fgraphemica.com%2F%25E2%2589%25A4&usg=AOvVaw3F85liV_DsJ9h3MDhA_F_j) 7%), using as reference the medium system, for all members of the family, then the performance test shall be performed on the “medium system configuration”.

$$δ=|\frac{\left(R\_{V/A, ref}-R\_{V/A, x}\right)}{R\_{V/A, ref}}|×100 (\%)$$

Where

$$R\_{V/A}=\frac{V\_{s,ref} }{A\_{a,ref} }=\frac{V\_{s,x} }{A\_{a,x} }$$

and:

*Vs,x*  is the fluid content of the storage tank of the actual ICS system configuration [l]

*Vs,ref*  is the fluid content of the storage tank of the reference ICS system configuration [l]

*Aa,x*  is the aperture area of the actual ICS system [m2]

*Aa,ref*  is the aperture area of the reference ICS system [m2]

If the variation of one system of the family is above this limit δ (>7%), then two systems shall be tested, that with the highest ratio of volume to aperture area (SH) and the one with the lowest ratio of volume to aperture area (SL).

*Note D.5.1: Collector aperture area is defined in ISO 9488; The total store volumes are declared by the manufacturer for all sizes in the ICS family. The plausibility of the declared data shall be checked by the testing laboratory.*

**D.5.2 Requirements for grouping different ICS system into one system family**

In order to be considered an ICS family all systems must meet the following

- the same materials shall be used for all components

-the length, width and volume can differ but shall be proportionate

-the members shall have the same external and internal design

One of the following methods shall be used to determine the performance of each system of the ICS family

* Method III (CSTG), as described in D.5.3
* Method IV (DST), as described in D.5.4

If δ[≤](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=10&cad=rja&uact=8&ved=0ahUKEwilnrXRm7rbAhXJe8AKHTvRDPcQFghdMAk&url=http%3A%2F%2Fgraphemica.com%2F%25E2%2589%25A4&usg=AOvVaw3F85liV_DsJ9h3MDhA_F_j) 7% the medium system is tested and used as reference system. If δ>7%, for any member of the family δL δH is checked. If δL>δH the system SH is considered as reference system. If δL<δH the system SL is considered as reference system.

**D.5.3 Method III (CSTG)**

This method can be used only when an ICS system is tested according to EN 12976-2 using ISO 9459-2. The methodological approach used to extend the test results to other systems of the family is illustrated in the following figure

Check requirements to determine the reference system or systems

Test reference system or systems according to EN12976-2 using ISO 9549-2 CSTG to obtain data sets for performance parameters identification

Extrapolation of performance parameters for other systems of the family

Test data sheets

Characteristics of other systems of the family:

* Aperture area
* Storage volume
* Storage dissipating surface

Calculation of QL and QD for each system of the family

Annual performance of all the systems of the family

Where:

QD is heat demand (result from EN12976) [MJ/year]

QL is heat delivered by the solar heating system (according to EN12976) [MJ/year]

The method is organized in the following steps:

1. Check of the requirements to extend test results to other systems of the family
2. Parameters identification and annual performance calculation for reference ICS system from experimental data sets
3. Extrapolation of performance parameters for other systems of the family
4. Calculation of annual performance of whole systems family

**D.5.3.1 Requirements to extend test results to other systems of the family**

* The reference ICS system shall be tested according to EN 12976-2 using ISO 9459-2 (CSTG method).
* All other systems of the family shall be characterized by a ratio between storage volume and aperture area, as required by D.5.1

**D.5.3.2 Data sets for reference ICS system**

From the tests carried out according to ISO 9459-2 (CSTG method), the typical experimental data sets relating to the daily thermal performances is given in the following table.

| **Data points** | **Data acquired during 12-h test** | **Draw-off** | **Output** |
| --- | --- | --- | --- |
| *H**MJ/m²* | *Ta(day)**°C* | *Tmain**°C* | *Ta(day) - Tmain**K* | *Vd**l* | *Td(max)**°C* | *Td(max) – Tmain**K* | *Q**MJ* |
| 1 | *H1* | *Ta,1* | *Tmain,1* | *…* | *3 Vs,ref* | *Td(max),1* | *…* | *Qref,1* |
| 2 | *H2* | *Ta,2* | *Tmain,2* | *…* | *3 Vs,ref* | *Td(max),2* | *…* | *Qref,2* |
| … | *…* | *…* | *…* | *…* | *…* | *…* | *…* | *…* |
| n | *Hn* | *Ta,n* | *Tmain,n* | *…* | *3 Vs,ref* | *Td(max),n* | *…* | *Qref,n* |

**Table D.5.3 – Experimental data set of reference ICS system**

In addition to the previous tests, other test for calculating the mixing draw-off temperature profile and the over-night heat loss coefficient of the storage tank, are performed. Starting from these data, the parameters needed for estimating the annual performance are calculated, as shown in the following parameter table.

|  |  |  |
| --- | --- | --- |
| **Performance parameter description** | **Symbol** | **Unit of measure** |
| Coefficients related to daily energy output of the system, obtained according to the following linear correlation:$$Q\_{ref}=a\_{1}H+a\_{2}\left(T\_{a(day)}-T\_{main}\right)+a\_{3}$$ | *a1* | m² |
| *a2* | MJ/K |
| *a3* | MJ |
| Storage tank heat loss coefficient | *Us, ref* | W/K |
| Normalized draw-off profile, evaluated for H > 16 MJ/m² and H < 16 MJ/m² | *f(V)* | - |
| Normalized mixing draw-off profile | *g(V)* | - |

**Parameter table – Reference system parameters for annual performance calculation**

**D.5.3.3 Extrapolation of performance parameters for other ICS systems**

The following paragraphs show how to extrapolate the parameters needed for the calculation of annual performance, for all locations and for all loads, for the other systems of the family

**D.5.3.4 Daily thermal performance of the system**

For every system of the family a new table x is composed. For each test day, the experimental data set related to the reference system (see table D.5.3), the daily thermal performance of the generic ICS system, in the same operating conditions as the reference system, are calculated according to the following formula:

$$Q\_{x}=Q\_{ref}\frac{A\_{a,x}}{A\_{a,ref}}$$

where:

Qx is the daily thermal energy output of the actual ICS system [MJ]

Qref  is the daily thermal energy output of the reference ICS system, obtained during the experimental tests [MJ]

Aa,x  is the aperture area of the actual ICS system [m2]

Aa,ref is the aperture area of the reference ICS system [m2]

| **Data points** | **Data acquired during 12-h test** | **Draw-off** | **Output** |
| --- | --- | --- | --- |
| *H**MJ/m²* | *Ta(day)**°C* | *Tmain**°C* | *Ta(day) - Tmain**K* | *Vd**l* | *Td(max)**°C* | *Td(max) – Tmain**K* | *Q**MJ* |
| 1 | *H1* | *Ta,1* | *Tmain,1* | *…* | *3 Vs,x* | *Td(max),1* | *…* | *Qx,1* |
| 2 | *H2* | *Ta,2* | *Tmain,2* | *…* | *3 Vs,x* | *Td(max),2* | *…* | *Qx,2* |
| … | *…* | *…* | *…* | *…* | *…* | *…* | *…* | *…* |
| n | *Hn* | *Ta,n* | *Tmain,n* | *…* | *3 Vs,x* | *Td(max),n* | *…* | *Qx,n* |

**Table x – Extrapolation of data of system x**

Starting from the daily thermal performance data thus obtained, the parameters a1, a2 and a3, related to the actual ICS system x, are calculated.

**D.5.3.5Storage tank heat loss coefficient**

This coefficient is calculated for the actual ICS system, according to the following formula:

$$U\_{S,x}=U\_{S,ref} \frac{A\_{tot,x}}{A\_{tot,ref}}$$

where:

Us,x is the storage tank heat loss coefficient of the actual ICS system [W/K]

Us,ref is the storage tank heat loss coefficient of the reference ICS system [W/K]

Atot,x  is the surface area of the store in the actual configuration [m2]

 Atot,ref is the surface area of the store in the reference configuration [m2]

**D.5.3.6 Normalized draw-off profiles**

For all members of the family the same normalized draw-off profiles f(V) and g(V), obtained for the reference ICS system, shall be used.

This assumption is based on the hypothesis that the fraction of thermal energy extracted from the reference storage tank, is the same of that extracted from the actual storage tank when the draw-off volume is properly scaled according to the ratio between the reference storage tank volume VS,ref and the actual one VS,x.

In particular, it is assumed that:

$${f(V\_{d}}/{V\_{s, ref})=f({V\_{d,x}}/{V\_{s, x}})}$$

$${g(V\_{d}}/{V\_{s, ref})=g({V\_{d,x}}/{V\_{s, x}})}$$

where:

 $V\_{d}$ is the draw-off volume referred to the reference ICS system [litre]

 $V\_{d,x}=V\_{d} \frac{V\_{s, x}}{V\_{s, ref}}$ is the corresponding draw-off volume to be extracted by the actual ICS system, such to have the same value of the normalized draw-off profile. [litre]

**D.5.3.7** **Calculation of annual performance of whole systems family and presentation on the SK datasheet**

The annual performance indicators for all locations and loads, according to the requirements of EN 12976-2, are calculated for the tested ICS system and for all members of the ICS family using the derives parameters as described above.

**D.5.4 Method IV (DST)**

Alternatively the DST method, according to ISO 9459-5, can be used to determine the performance of an ICS system. In this case the reference system is defined in D.5.2. The DST method defines the following parameters:

* Effective collector area AC (m2)
* Total store heat loss US [W/K]
* Total store heat capacity CS
* Mixing constant DL
* Volume V [litre]

The extrapolation of the parameters for the different systems of the family is as following:

The effective collector area is scaled with the total surface of the aperture area$ $

$Ac,x$\*$=\frac{Ac,ref Ax}{Aref}$

The total store heat loss is scaled up with totals surface of aperture area

U$s,x=\frac{Us,ref Ax}{Aref}$

The total store heat capacity is scaled up with volumes

$$Cs,x=\frac{Cs,ref Vx}{Vref}$$

The mixing constant is kept constant for all the members of the family.

The volume is indicated by the manufacturer (see Note D5.1)

**D.5.4.1 Calculation of annual performance of whole systems family and presentation on the SK datasheet**

The annual performance indicators for all locations and loads, according to the requirements of EN 12976-2 5.9.3.2, are calculated for the tested ICS system(s) and for all other systems of the family using the definitions given above.

**D.5.5 Other required tests**

Apart from the performance test the mechanical load and the over temperature protection test shall be performed for the determination of performance of ICS family system (EN12976-2 5.5 and 5.2). The mechanical test shall be performed on the model of the family with the highest aperture area. The high temperature protection test shall be performed on the model having the highest ratio of aperture area (m2) to volume (litres).

1. The software SOLEN has been developed by the CSTB, is free and can be downloaded at the following website link : <http://enr.cstb.fr/webzine/preview.asp?id_une=217> [↑](#footnote-ref-1)