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INTERNATIONAL STANDARD

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Solar thermal electric plants –
Part 5-2: Systems and components – General requirements and test methods for large-size linear Fresnel collectors

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FOREWORD

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The text of this International Standard is based on the following documents:

Draft	Report on voting
117/148/CDV	117/160/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 62862 series, published under the general title *Solar thermal electric plants*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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SOLAR THERMAL ELECTRIC PLANTS –

Part 5-2: Systems and components – General requirements and test methods for large-size linear Fresnel collectors

1 Scope

This part of IEC 62862 specifies the requirements and the test methods for the characterization of a large-size linear Fresnel collector.

This document covers the determination of optical and thermal performance of linear Fresnel collectors, and the tracking accuracy of the collector one-axis tracking system. This test method is for outdoor testing only.

This document applies to linear Fresnel collectors according to Annex A equipped with the manufacturer-supplied sun tracking mechanism.

The testing method in this document does not apply to any collector under operating conditions where phase-change of the fluid occurs. Although the principles of this document can be applied also to collectors with phases-change, however, the sensors (enthalpy, flow, temperatures) required for that are not described in this document.

This document applies to the whole collector field in-situ or as a minimum unit to be tested to an individual collector string (loop) connected to the main piping (flow, return flow) to and from a heat sink, covering the full temperature range of the field.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC TS 62862-1-1, *Solar thermal electric plants – Part 1-1: Terminology*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO 9488, *Solar energy – Vocabulary*

ISO 9806:2017, *Solar energy – Solar thermal collectors – Test methods*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9488, ISO 9806:2017, IEC TS 62862-1-1, and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.2 Symbols

A_G	Gross collector aperture area (projected mirror area on the ground including the small gaps between facets and positioning of the mirrors for the sun in the zenith)	m²
C_R	Geometric concentration ratio: gross collector aperture area A_G divided by the surface area of the receiver A_R	-
E_L	Long-wave infrared sky radiation	W/m²
F_c	Ratio between the optical efficiency of the collector for normal incidence in a soiled state and a clean state.	-
f_{end}	Function describing the optical end loss of a collector with finite length when the sun is in the longitudinal collector plane	-
G	Solar irradiance	W/m²
H_{rec}	Height of receiver above mirror plane	m
K_b	Incidence angle modifier for direct beam irradiation	-
K_d	Incidence angle modifier for diffuse irradiation	-
K_T	Incidence angle modifier for direct beam irradiation in the transversal plane	-
K_L	Incidence angle modifier for direct beam irradiation in the longitudinal plane	-
L_m	Length of primary mirror row in one collector module	m
L_{rec}	Length of receiver in one collector module	m
$\dot{Q}$	Thermal power net output of the collector	W
T_m	Mean fluid temperature	K
T_a	Ambient temperature	K
u	Wind speed	m/s
W_i	Project width of mirror row i on the horizontal	m
W_c	Collector width (Width of mirror field perpendicular to row orientation in one collector module)	m
ρ_{test}	specular reflectance of the soiled primary mirrors	-
ρ_{nom}	specular reflectance of the clean primary mirrors	-
θ_{LS}	Longitudinal solar incidence angle	°
θ_T	Transversal incidence angle	°
$\chi_{reflector}$	Ratio of specular reflectance of soiled and clean mirror material	-
η_{0b}	Collector optical efficiency for direct beam radiation at normal incidence	-

Indices

a	ambient
b	beam
dif	diffuse

L	longitudinal
n	normal
T	transversal
Tilt	tilted

4 Testing requirements

The linear Fresnel collector shall be equipped with all the components supplied by the manufacturer (such as support structure, primary reflectors, receiver casing and support, receiver tubes, actuator system and control) and mounted according to the manufacturer instructions.

The different component/elements (such as the receiver parts, reflectors, mirror drives, structure) should be previously tested separately by current testing methods or standards when available. The documentation to be fulfilled by the manufacturer shall be according to Annex B.

5 Instrumentation

5.1 Solar radiation measurement

Solar radiation measurement shall be performed using a pyrheliometer for direct irradiance according to 21.1 of ISO 9806:2017.

Incidence angles will be determined by calculation or with sun position sensors with accuracy equal or better than ± 0,1° with a resolution of 0,01°.

5.2 Flow rate measurement

Flow rate measurement shall be performed according to 21.4.1 of ISO 9806:2017.

5.3 Temperature measurements

Temperature measurements (inlet, outlet and ambient temperature) shall be performed according to ISO 9806:2017 with an accuracy better than 1 % of the temperature rise over the collector

The collector inlet and outlet positions shall be defined by the manufacturer and pairwise calibrated temperature sensors shall be installed at no more than 200 mm from this point. If due to constructional constraints it becomes necessary to position the sensor more than 200 mm away from the collector, then a test shall be made to verify that the measurement of fluid temperature is not affected.

The problems caused by the concentrated light on the sensors if the sensors are mounted in the focus zone shall be taken into consideration.

For piping diameters larger than 254 mm, 2 to 3 temperature sensors should be considered for each position to have a more representative average.

5.4 Wind speed measurement

The mean wind speed in the horizontal plane shall be determined with a standard uncertainty < 0,5 m/s. The sensor shall be installed at (10 ± 0,1) m height from the ground. The sensor shall be installed within the collector field / solar plant. If there is no wind speed sensor close enough to the meteorological station of the plant, one temporary sensor should be added at a distance from the collector extremity (end support as shown in Figure A.1) not larger than 100 m away.

5.5 Data acquisition

Data acquisition shall be according to 23.5.3 of ISO 9806:2017.

5.6 Tracking accuracy measurement

Experimental tracking accuracy measurements can be obtained using inclinometers. Resolution of the inclinometers shall be at least 0,01° and accuracy shall be better than 0,1° over the whole range of tracking angles. Combination of two or more inclinometers often solves this requirement.

The true tracking angle is measured at two locations of the collector, one near the centre (where the drive system is usually located) another one at one collector end.

A more detailed tracking error testing is optional (see 6.3.3).

6 Test procedure

6.1 General

Performance testing includes at least the assessment of the heat power delivered by the collector under various operating and environmental conditions and the measurement of the dependence of the thermal performance on the incidence angle of the irradiation onto the collector. These two sets of parameters are required for the calculation of the collector heat output. If possible, an effective thermal capacity according to ISO 9806:2017 should be also determined. A minimum collector unit (Figure 1) as already stated in the scope may be a complete collector row, a loop or even a subfield, covering the whole temperature range of operation.

6.2 Collector description

The description of collector(s) should be supplied by the manufacturer according to Annex B.

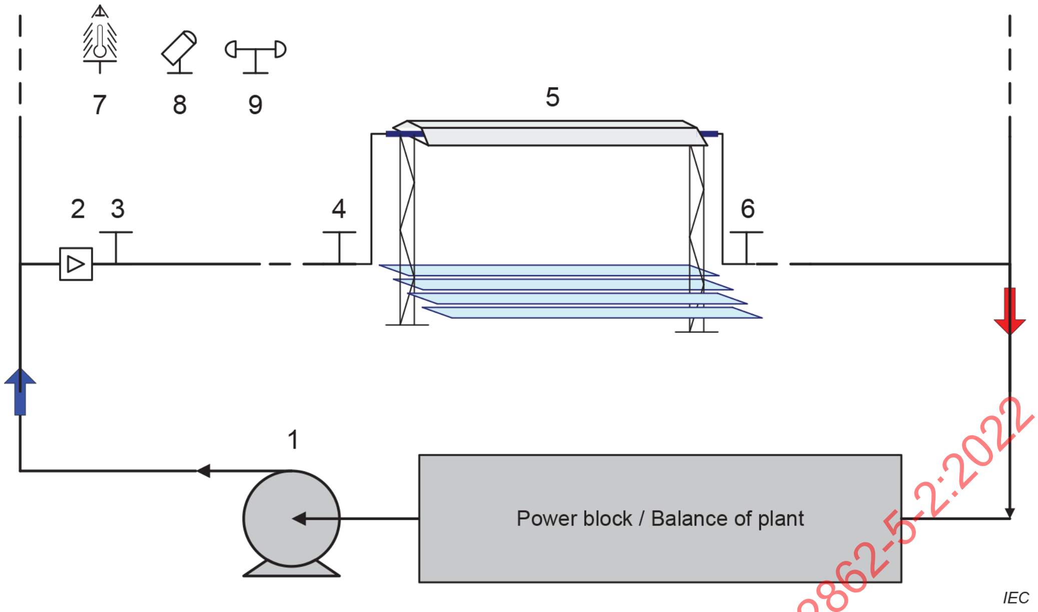
All the components of the tested collector (reflectors, receiver, structure, etc.) shall be representative of the product. The components shall have been selected randomly from the production during the erection of the collector.

All the serial numbers and identification of those components should be reported in the testing report.

6.3 Test equipment

6.3.1 Performance test

The sensors shall be mounted according to ISO 9806:2017. A scheme of principle for the test installation is presented in Figure 1.



Key

1	pump
2	flow meter
3	temperature sensor
4	temperature sensor (T_{in})
5	linear Fresnel collector unit
6	temperature sensor (T_{out})
7	ambient temperature sensor (T_a)
8	direct solar irradiance sensor
9	anemometer

Figure 1 – Test equipment installation

During the tests of a linear Fresnel collector it will be necessary to guarantee that the reflectors and glass envelopes of the receivers are kept clean. For testing purposes, the cleanliness factor is defined as the ratio between the average optical efficiency during the test and the optical efficiency with ideal clean surfaces. Depending on the receiver construction, not only the cleanliness of the primary mirrors, but to a lesser degree also soiling of the tubular or plane glass cover, and the secondary reflector may impact the collector cleanliness. The target is to keep the collector's cleanliness factor F_c within the range 0,95 < F_c < 1,0.

6.3.2 Optical characterization for performance testing

6.3.2.1 Cleanliness

If possible, the collector components primary mirrors, secondary mirrors and cover glasses should be cleaned before the testing. However, in outdoor testing soiling may occur continuously. Therefore, it is important to determine the average cleanliness of a collector before and after a performance test in order to be able to relate the results to a maximum performance with clean mirrors.

The reflectance of the primary mirrors ρ_{nom} (clean state) and ρ_{test} (soiled) will be measured with a portable reflectometer. ρ_{nom} and ρ_{test} shall be measured with the same equipment.

So far there is no field instrumentation available to determine the degree of dirt in the receiver cover and on a secondary reflector once installed in the collector; as the receiver faces the ground it is assumed a good approach to neglect the much smaller percentage of reduction in optical efficiency due to soiling during the test period of the cleaned glass cover and secondary mirror compared to fast soiling of primary mirrors.

The determination of cleanliness on the primary mirrors during the test period is mandatory. If the average global cleanliness factor F_c falls below 0,95, the collector (both reflectors and transparent covers) should be cleaned as a consequence for the next measurement period.

6.3.2.2 Mirror shape quality

Optionally the quality of the mirror shape may be tested in the laboratory by an appropriate means, if the measured thermal performance and the theoretical or simulated performance show huge difference. For example deflectometry, fringe reflection techniques or a similar technique may be used to check the quality for individual mirror shapes. See Annex D.

6.3.3 Tracking error test

The solar tracking systems should be installed and calibrated according to the manufacturer's recommendations.

Optionally the tracking accuracy of individual mirror rows may be tested, if the measured thermal performance and the theoretical or simulated performance show huge difference. See Annex E.

6.4 Measurement procedure

6.4.1 General

The thermal performance test to determine optical efficiency at normal incidence , heat losses and incidence angle modifier shall be performed according to ISO 9806:2017 using the quasi-dynamic test method (QDT) or the dynamic test method (DT) specified by the SolarPACES DISPAT Guideline [4][1] (see also [3]). The wind speed shall be less than 5,5 m/s during the testing period. The testing shall be performed outside under real weather conditions. In order to identify measurement periods for QDT with suitable environmental conditions, the specifications of ISO 9806:2017 apply. For DT the specifications shall be similar for the test period, however the requirements on the stability of irradiance or temperature conditions do not apply.

6.4.2 Cleanliness

The assessment of cleanliness shall be based on primary mirror reflectance measurements using the SolarPACES Guideline on mirror reflectance [1]. There should be a measurement of at least 3 clean samples to assess the "clean" reflectance ρ_{nom} of a mirror as the average value.

The determination of cleanliness from reflectance-measurements should be done for each test day. Cleanliness of the collector to be tested shall be measured after performing a cleaning procedure and at the end of the measurement day. It should be measured at least on 10 different positions (select random primary mirror rows at each position).

The reflectors cleanliness factor $\chi_{reflector}$ is determined for each sequence of the test at least in 10 positions of the collector considered. If the values of reflectance differ by more than ±5 % points, the average of 20 different positions should be taken. The number and position of points measured should be reported in the test report.

The global collector cleanliness is approximately estimated by Formula (1), only taking into account the effect of primary mirror soiling:

[1] Numbers in square brackets refer to the Bibliography.

$$F_{\mathrm{C}} \cong \chi_{\mathrm{reflector}} = \frac{\bar{\rho}_{\mathrm{test}}}{\rho_{\mathrm{nom}}} \quad (1)$$

Where

$\bar{\rho}_{\mathrm{test}}$ is the arithmetic average of measurements of ρ_{test} before and after each test sequence,

ρ_{test} is the specular reflectance measured of the primary reflectors of the collector, and

ρ_{nom} is the reference value of the specular reflectance of the primary reflector material installed in the collector.

The secondary mirror may be also qualified if accessible to measurements (uncovered receiver cavity).

If the receiver tube is covered by a cover glass (cylindrical, plane) the cleanliness should be also evaluated after cleaning using the portable reflectometer, if that is feasible. A temporary black background behind the sheet of glass at the measurement position is recommended. In this case Formula (1) may be modified accordingly.

6.4.3 Test conditions

6.4.3.1 Quasi-dynamic testing

The test conditions as specified in ISO 9806:2017, Clause 23 shall be applied as far as possible. In real installations however the variation of collector input temperature might be limited and it could be impossible to fully cover the whole allowed temperature range of operation.

6.4.3.2 Dynamic testing

With the DT method the conditions to be fulfilled are not restricted to steady-state. Neither the inlet temperature nor the mass flow rate has to be kept constant, in addition to accepting any variation of the direct irradiance. In real installations however the variation of collector input temperature might be limited and it could be impossible to fully cover the whole allowed temperature range of operation.

All test day types as described in ISO 9806:2017, 23.6.2 for QDT shall be included in the test period used for DT.

6.5 Calculation and test results evaluation

6.5.1 General

Calculation of the test results shall be performed according to Clause 24 of ISO 9806:2017 for the quasi-dynamic test method QDT and using similar modelling formulas for the dynamic test method DT specified by the SolarPaces DISPAT Guideline [3],[4].

The increase of specific enthalpy of the fluid within the collector Δh is equal to $\Delta h = h_{out} - h_{in}$. Polynomial approximations or interpolation of tabulated values can be used for the specific enthalpy $h(T)$ of the heat transfer fluid.

The fluid data table of the specific enthalpy (or specific heat capacity) depending on the temperature shall be measured in the entire working range by a laboratory, any other independent body or obtained from a referenced literature data. This data shall be documented and referenced.

The experimental useful power output therefore has to be determined for each time-step as $\dot{Q} = \dot{m} \times \Delta h = \dot{m} \times (h_{out} - h_{in})$.

6.5.2 Useful power

The general single node model of the collector according to ISO 9806:2017 is written as Formula (2) using a parametrization of optical characteristics and thermal losses.

$$\dot{Q} = A_{\mathrm{G}} \left[\begin{array}{l} \eta_0 \left(K_{\mathrm{b}} \left(\theta_{LS}, \theta_T \right) G_{\mathrm{bT}} + K_d G_{dif} \right) - a_1 \left(T_{\mathrm{m}} - T_{\mathrm{a}} \right) - a_2 \left(T_{\mathrm{m}} - T_{\mathrm{a}} \right)^2 - a_3 u \left(T_{\mathrm{m}} - T_{\mathrm{a}} \right) - \\ a_4 \left(E_L - \sigma T_a^4 \right) - a_5 \left(\frac{dT_{\mathrm{m}}}{dt} \right) - a_6 u G_{hem} - a_7 u \left(E_L - \sigma T_a^4 \right) - a_8 \left(T_{\mathrm{m}} - T_{\mathrm{a}} \right)^4 \end{array} \right] \tag{2}$$

Simplifications are set for collectors depending on the receiver type and concentration. For collectors where

- The sky is shielded from the receiver tubes by a cover or cavity: $a_4 = a_7 = 0$.
- Receiver tubes are protected from wind by a transparent cover (cover may be flat or tubular glass): $a_3 = a_6 = 0$.
- The geometric concentration ratio is higher than 20, $K_{\mathrm{d}} = a_4 = a_6 = a_7 = 0$.

In this case the collector model would be given by Formula (3) assuming that with a good tracking:

$$\dot{Q} = A_{\mathrm{G}} \left[\eta_{0,\mathrm{b}} K_{\mathrm{b}} \left(\theta_{LS}, \theta_T \right) G_{\mathrm{bT}} - a_1 \left(T_{\mathrm{m}} - T_{\mathrm{a}} \right) - a_2 \left(T_{\mathrm{m}} - T_{\mathrm{a}} \right)^2 - a_5 \left(\frac{dT_{\mathrm{m}}}{dt} \right) - a_8 \left(T_{\mathrm{m}} - T_{\mathrm{a}} \right)^4 \right] \tag{3}$$

Alternatively to G_{bT} also the direct normal irradiation G_{bn} (DNI) may be used, with the incidence angle modifiers K' including the cosine effect on the aperture: $K'_{\mathrm{b}} = K_{\mathrm{b}} \cos(\theta)$.

In case the receiver tubes are evacuated tubes the infrared radiation transport is dominating and convection-conduction inside the tubes is negligible, therefore in this case a_2 should be set to zero (Formula 4a). In all other cases the convection is not negligible and instead $a_8=0$ (Formula 4b) should be used:

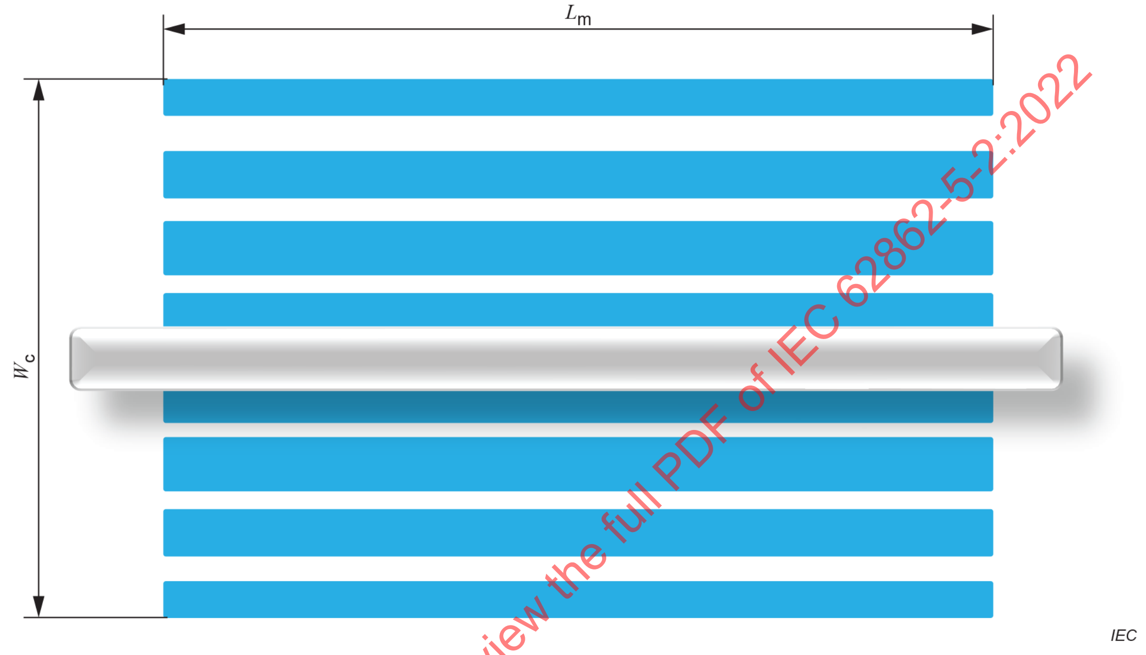
$$\dot{Q} = A_{\mathrm{G}} \left[\eta_{0,\mathrm{b}} K_{\mathrm{b}} \left(\theta_{LS}, \theta_T \right) G_{\mathrm{bT}} - a_1 \left(T_{\mathrm{m}} - T_{\mathrm{a}} \right) - a_5 \left(\frac{dT_{\mathrm{m}}}{dt} \right) - a_8 \left(T_{\mathrm{m}} - T_{\mathrm{a}} \right)^4 \right] \tag{4a}$$

$$\dot{Q} = A_{\mathrm{G}} \left[\eta_{0,\mathrm{b}} K_{\mathrm{b}} \left(\theta_{LS}, \theta_T \right) G_{\mathrm{bT}} - a_1 \left(T_{\mathrm{m}} - T_{\mathrm{a}} \right) - a_2 \left(T_{\mathrm{m}} - T_{\mathrm{a}} \right)^2 - a_5 \left(\frac{dT_{\mathrm{m}}}{dt} \right) \right] \tag{4b}$$

A_{G} is the solar collector gross aperture area (see definition in IEC TS 62862-1-1), as shown in Figure 2, L and W_{i} the gross length and projected width of a reflector module, and N the number of reflectors, respectively.

$$A_G = N \times L_m \times \sum_{all\ mirror\ rows\ i} W_i \quad (5)$$

The solar collector gross aperture includes the small gaps between mirrors in a line, however it excludes the large gaps between mirror rows or between collector modules connected in series. The projected width of mirrors below the receiver is included even when parts are shaded in the position where the sun is in the zenith.



Key

L_m mirror length

W_c collector width

Gross aperture area definition: N primary mirrors should be oriented for the sun in the zenith position.

Figure 2 – Sketch of one module of linear Fresnel collector as seen from above

Formula 4a will be preferred, with a_8 parameter for heat losses. If the sum of residuals of the modelled and measured values is smaller with Formula 4b, and the *t-ratio* (parameter value/standard deviation of parameter) of the a_8 parameter is less than 3, then Formula 4b will be used, with a_2 parameter for heat losses.

6.5.3 Incidence angle modifier (IAM)

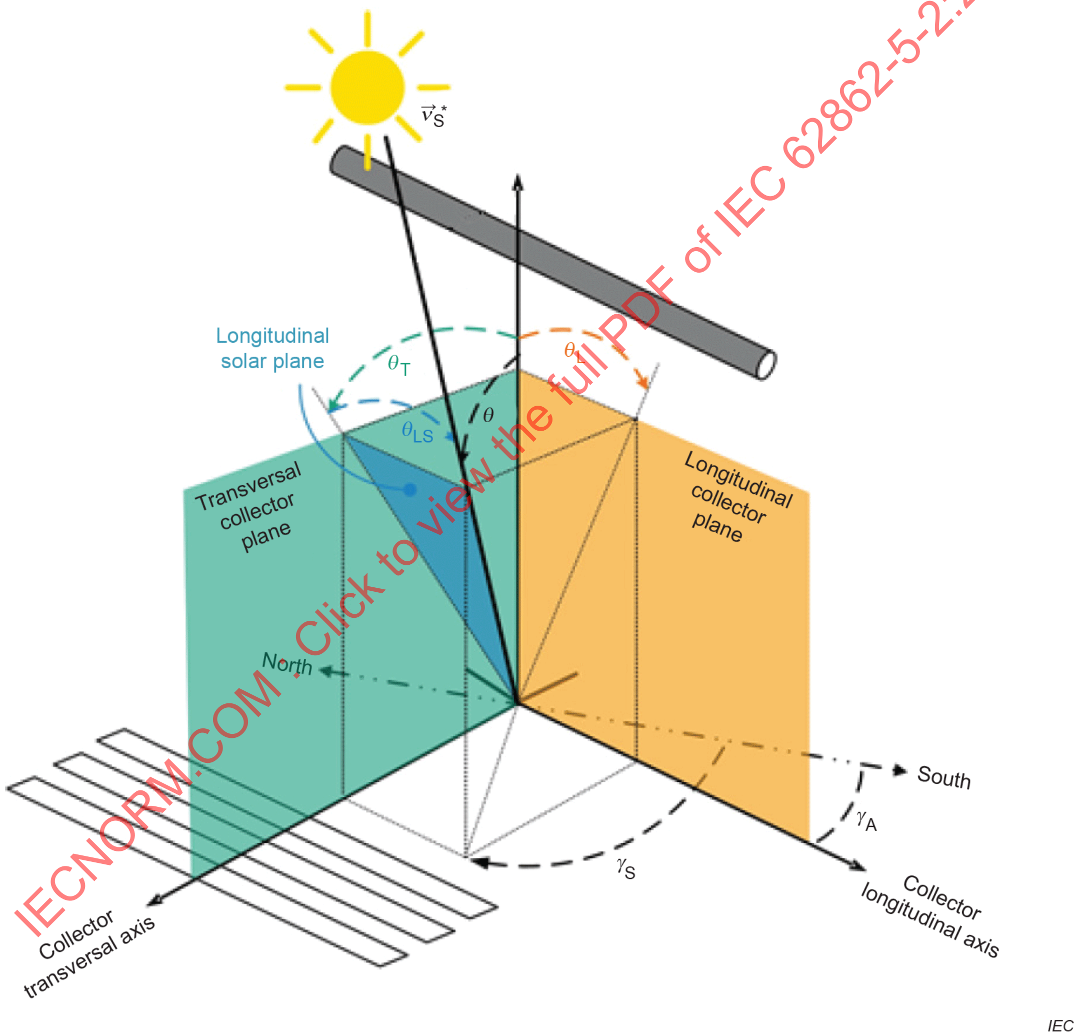
When the incidence angles are different from 0° ($\theta_{LS} \neq$ 0° or/and $\theta_T \neq$ 0°), the value of the incidence angle modifier, $K(\theta_{LS};\ \theta_T)$, is obtained from Formula (6). The set of values $K_L(\theta_{LS})$ and $K_T(\theta_T)$obtained as function of the solar incidence angles θ_{LS} and θ_T (see Figure 3) shall be determined as a list of values in tabular form representative for discrete values in intervals of maximum 10° in the range of 0° to 60° and maximum 15° between 60° and 90”. The values for 90° incidence are set to zero. The functions $K_L(\theta_{LS})$ and $K_T(\theta_T)$ for specific angles shall be interpolated linearly between two angles:

$$K(\theta_{LS};\ \theta_T) \cong K_L(\theta_{LS}) \times K_T(\theta_T) \quad (6)$$

If the Fresnel collector is non-symmetric, positive and negative angles are required for both angles. The signed convention angles shall be defined in the testing report. It should be recalled that the end-losses f_{end} (see Formula (10)) have to be included in the useful power Formula (4), because the function K defined in Formula (5) is valid for an infinitely long collector [4]. Both QDT and DT methods allow a direct assessment of the biaxial (two-dimensional) IAM-matrix values of a LFR. The values of the IAM along the transversal and longitudinal axis can be read in and be optimized automatically according to the measured data.

The longitudinal incidence angle modifier function $K_L(\theta_{LS})$ shall not include the end-effect of a finite collector [2].

It is recommended to use a tabulated incidence angle modifier with linear interpolation between the sampling points.



Key

θ_{LS} longitudinal solar incidence angle

θ_T transversal incidence angle

Figure 3 – Incidence angles for a linear Fresnel collector

From Figure 3 the calculation of the different incidence angles can be derived:

$$\theta_{\mathrm{T}} = \tan^{-1}(\,|\sin\gamma| \times \tan\theta_{\mathrm{z}}) \tag{7}$$

$$\theta_{\mathrm{L}} = \tan^{-1}(\cos\gamma \times \tan\theta_{\mathrm{z}}) \tag{8}$$

$$\theta_{\mathrm{LS}} = \sin^{-1}(\cos\gamma \times \sin\theta_{\mathrm{z}}) \tag{9}$$

The effect of finite length of mirror rows and receiver for longitudinal solar angles larger than 0° is approximately described in the following formula (for equal length of receiver and mirror rows with no offset of the two components).

$$f_{\mathrm{end}}(\theta_{\mathrm{LS}}) = 1 - \frac{H_{\mathrm{eff}}}{L_{\mathrm{rec}}} \tan(|\theta_{\mathrm{LS}}|) \tag{10}$$

$$H_{\mathrm{eff}} = \sqrt{\left(\frac{W_{\mathrm{c}}}{4}\right)^2 + H_{\mathrm{rec}}^2} \tag{11}$$

Alternatively to a linear interpolation it may be possible to use for each 1D incidence modifier function a polynomial in incidence angle or incidence angle cosine. The order of the polynomial has to be high enough to be able to represent the angular function. This can be tested by varying the order and check the variation of the functions.

Alternatively to measuring experimentally the IAM in the range of incidence angles θ_T and θ_{LS} accessible for the location of the test, it is possible also to calculate the complete two-dimensional range of IAM from ray-tracing, using the geometry of the collector and the optical properties of mirror and receiver materials. and then check for a selection of minimum 5 defined pairs of angles and measure the IAM there. The difference between experimental and theoretical IAM should be less than 5 % points.

6.5.4 Evaluation for the quasi-dynamic test method QDT

The QDT method is based on measurements taken in approximately steady state over a certain time period and a determination of collector parameters according to the basic test Formula (3) using least-square fitting methods (multi-linear regression MLR), which is a fast matrix method that allows a non-iterative parameter fit. Formulas (3) to (11) are used to adapt the general formula for the specific case. The MLR is used to minimize the difference between the power output measured and the power output calculated using the parameters a_i, IAM values, and end-loss factor. Note that the IAM values that can be determined with the QDT method are related to the accessible angles during the testing days, due to the Sun's diurnal paths.

Without the loss of generality, no well-known physical model exists for the incident angle modifier on longitudinal solar plane $K_{\mathrm{L}}(\theta_{\mathrm{LS}})$ and on the transversal solar plane $K_{\mathrm{T}}(\theta_{\mathrm{T}})$. The complexity that represents a two-dimensional model of the IAM, as compared to simpler models, is commonly solved by complementing the adjustment of the MLR with an additional mathematical formulation. Sallaberry *et al.* [5] used the so called "dummy variables" method with angular ranges of ±1°. Hofer *et al.* [3] expanded the MLR-method with an iterative procedure to be able to determine the IAM-values in the longitudinal and transversal directions. Note that the IAM values can be provided only within the respective validity ranges of the measurements.

6.5.5 Evaluation for the dynamic test method DT

As the objective of the DT method is the evaluation of the dynamic performance of a collector, a numerical simulation model is required that shall reproduce the dynamic behavior of the collector. To this end, any dynamic simulation model can be used, mostly incorporating a discretization of the (simplified) Navier-Stokes formulas. Along the fluid flow the collector is segmented therefore in a number of *N* nodes.

The method uses the comparison of the power output measured with the power output simulated in the numerical tool. The simulation model therefore needs parameters to quantify optical performance and thermal losses. Then the parameter identification method as sketched in Figure 4 will be used, where an optimization method is used to find the parameters for which the agreement between the two power output time series is best (least-squares minimization).

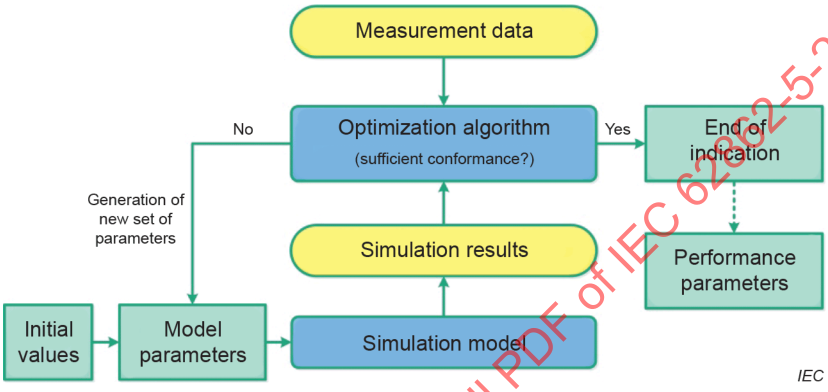


Figure 4 – Sketch of parameter identification procedure used for the DT method [3]

For compatibility to QDT the modelling of the energy balance on the individual absorber nodes should use the parameters of Formulas (2) resp. (4). One approach to model the system is to calculate the collector power output as a sum over the gains and losses of every collector node (*n*) as follows:

$$\dot{Q}_{\text{col\_sim}} = \sum_{n=1}^{N} (\dot{Q}_{\text{abs,n}} - \dot{Q}_{\text{loss,n}}) \tag{12}$$

For example the solar radiation incident on the absorber $\dot{Q}_{\text{abs}}$ and the heat loss of the absorber $\dot{Q}_{\text{loss,n}}$ could be written as:

$$\dot{Q}_{\text{abs}} = \dot{Q}_{\text{abs,n}} \times N = \eta_{0,\text{b}} \times K(\theta_{\text{LS}};\ \theta_{\text{T}}) \times f_{\text{end}}(\theta_i) \times G_{\text{bT}} \times A_{\text{G}} \tag{13}$$

$$\dot{Q}_{\text{loss,n}} = \frac{A_{\text{G}}}{N} \times \left[a_1 \times (T_{\text{m,n}} - T_{\text{a}}) + a_2 \times (T_{\text{m,n}} - T_{\text{a}})^2 \right] \tag{14}$$

In this approach, the end losses are considered with the parameter $f_{\text{end}}(\theta_{\text{i}})$, and a_1 and a_2 are parameters identified during the evaluation, along with $\eta_{0,b}$, $K(\theta_{\text{LS}};\theta_{\text{T}})$.

Summing up the solar radiation incident on the absorber segments $\dot{Q}_{abs,n}$ and the respective heat losses $\dot{Q}_{loss,n}$, one ends up with a parametrization similar as for QDT. The thermal loss would be calculated in the case of DT for each single node n, whereas for QDT it would be characterizing the complete collector (field). Using the approach of Formula (2) the resulting collector power would neglect capacity and time-lag effects (the response of a change in inlet temperature is not immediately seen in the output), so it would be realistic only for small collectors. Larger collectors need a formulation which take into account these effects for each time-step, namely by comparing inlet and outlet for the same time-step:

$$\dot{Q}_{out} = \dot{m}\left(h_{out} - h_{in}\right) \tag{15}$$

With the DT method the evaluation procedure is not limited to the linear and quasi steady-state collector Formula of the QDT-method (2), where inlet temperature variations are restricted to ±1 K during each test sequence. Therefore, neither the inlet temperature nor the mass flow rate has to be kept constant, in addition to accepting any variation of the irradiance. For the DT method starting values of the biaxial (two-dimensional) IAM-matrix of a LFR can be read in during the process in Figure 4 and will be optimized automatically.

6.5.6 Validation performance test

6.5.6.1 General

The validation test shall compare the power output for a specific validation period compared to the calculated (QDT) or simulated (DT) power output of the collector using the parameters determined in the performance test in 6.5.4 and 6.5.5 using the measured meteorological data of the validation period.

6.5.6.2 Comparison of calculated and measured power output for quasi-dynamic testing

During the validation period the collector shall be in operation for 2 typical operational days with clear sky (the times with heat production shall be at least 4 h per day, 2 h before noon and 2 h after noon), each day with at least 2 different fluid inlet temperature T_{in} over the two days, (differing at least 10 K) and producing heat within the normal working temperature range of the collector. In the case of the quasi-dynamic test method the requirements on measurement accuracy and steady state stability shall be the same as in the thermal performance test.

The validation consists in the comparison of the useful power output from collector calculated according to Formula (4a) or Formula (4b) using the parameters determined in 6.5.4. As the range of combinations $(\theta_{LS};\ \theta_T)$ does not cover all possible angle combinations over a year, the validation of the complete IAM needs to be performed by other means (raytracing simulation, testing during several periods of a year)

The recommended time-averaged difference between the calculated and measured power – corrected for cleanliness differences - should be within ±5 %.

6.5.6.3 Comparison of calculated and measured power output for dynamic testing

In the case of the dynamic test method, the test parameters determined in 6.5.5 may have been found by optimizing a simulation using several time-series data sets from several test periods. Similarly here the range of combinations $(\theta_{LS};\ \theta_T)$ may not cover all possible angle combinations over a year if not periods from different seasons are used.

To validate the characterization, the useful power output for the validation period, 2 additional typical operational days with clear sky, from the collector shall be simulated using the identified parameters in the simulation tool and the same meteorological input as in the validation period. It shall be compared to the measured power output in the validation period.

The recommended time-averaged difference between the simulated and measured power should be within ±5 %.

6.5.6.4 Optical efficiency for normal incidence (optional)

The optical efficiency for normal incidence is defined as the optical efficiency for the sun in the zenith ($\theta_{LS}=0$; $\theta_T=0$) even if there may be angular positions where the optical efficiency is higher due to special configurations (e.g. due to shading of mirrors by the receiver structure). It should be calculated theoretically using raytracing or other techniques to determine blocking, shading and spillage losses of the collector geometry, and the optical properties provided from the receiver and reflectors manufacturers (transmittance of glass cover, absorptance of receiver tube and reflectance of the primary and secondary reflectors). Usually a good design has no shading and blocking losses for normal incidence. Therefore the optical losses depend very much on the receiver aperture and the internal reflections in a receiver cavity (with secondary reflector). Raytracing with ideal components (mirror shape, minimum beam spread) and the correct circumsolar distribution should give an upper limit of the optical efficiency. If actual data on mirror shape (see Clause D.1) are available, more realistic results for optical efficiency can be obtained.

The recommended difference between the determined optical efficiency by ray-tracing and as identified from experiment using Formula (3) or Formula (4) should be within ±5 %. If the difference is higher at least the receiver cover and mirror material test results as well as the mirror shape data provided by the manufacturers of the single components and the focal lengths of the mirrors may be analysed and reported.

6.5.7 Tracking error test (optional)

6.5.7.1 General

An optional tracking error test (see 6.3.3) should be analysed according to the following subclauses. The testing does not need to be recorded continuously until enough data sets are sampled.

6.5.7.2 Data binning by wind speed

The data have to be at least separated into low and high measured wind speed bins using 4 m/s as the threshold value.

Two bins represent a compromise to minimize test duration, complexity, and cost. The manufacturer may choose to report tracking accuracy statistics for additional wind speed bins and include its relationship with wind direction.

If the solar tracker has a sun sensor filter for minimum irradiance (optional), all data recorded with a direct normal irradiance that is less than 250 W/m^2 should be removed.

6.5.7.3 Data quantity

For each of the binned data sets as defined above (“low wind, min error measurement”, “high wind, maximum error measurement”, etc.), ensure there are a sufficient number of data points.

The data from each tracking error sensor shall satisfy these criteria:

- At least 360 data points after the above filtering over the whole tracking range of the collector.
- At least 5 separate days, with at least 50 data points per day.
- At least 180 points each for low and for high wind speed.
- At least 50 data points before noon and 50 points after noon with the points being distributed at equal time intervals between sunrise and sunset.

6.5.7.4 Accuracy calculations

For each of the data sets, calculate the following two values:

- Typical accuracy: the median value of the tracking error over the filtered data set. As all recorded tracking error values will be positive values, the "typical accuracy" will be a value greater than zero but less than the 95th percentile accuracy.
- 95th percentile accuracy: the 95th percentile value of the tracking error over the filtered data set. That is, 95 % of the measured data points fall below this error.

NOTE 95th percentile accuracy in no way implies that the tracking accuracy statistics follow rules for a normal distribution.

6.5.8 Uncertainty estimation

The calculation of standard uncertainty of the characteristic parameters describing the optical and thermal performance, calculated applying the test method described in this document, follows the rules established by ISO/IEC Guide 98-3 and Annex D of ISO 9806:2017.

7 Reporting format

The final report on the optical and thermal performance of the tested linear Fresnel collector shall include detailed information of:

- The tested linear Fresnel collector description.
- The test setup (description of the test facility where the collector has been tested, sensors and other equipment used to measure the variables needed to apply this test method).
- The result of the determined model parameters accompanied with their corresponding uncertainty values.
- The result of tracking error characterization (optional).
- Graph to show the data set of the variables measured during the tests leading to the final result, according to ISO 9806:2017, Figure 9 (in this case, $t_m - t_a$ vs DNI) and Figure 10 (DNI vs θ_i).

The contents of the report shall be structured according to Annex C.

Annex A
(informative)

Linear Fresnel collector description

A.1 General description

A.1.1 Overview

A linear Fresnel collector is a line-focus solar collector (see IEC TS 62862-1-1) that concentrates the solar radiation by means of reflector facets with slightly curved cross-section, arranged in long mirror rows. It is composed of a set of modules connected in series driven by a common drive unit and with only one sun-tracking system as one extreme, or modules with individual mirror drives and many drive units on the other extreme. A receiver with one or more tubes is located at the focus line of the mirrors. The receiver cavity or casing – optionally including a secondary reflector - is mounted on a mechanical support system that includes steel supports and bearings. Each linear Fresnel collector includes local instruments, a hydraulic or electromechanical drive system, and its own local controller via which it independently tracks the sun, and maintains reflector focused on the receiver.

The linear Fresnel collector is the basic functional unit for a collector loop in a solar field (Figure A.1). Each linear Fresnel collector usually consists of a repetitive arrangement of modular units. A collector typically contains the following elements:

- A series of modular units separated by support structures.
- One or more drive supports.
- Several middle supports with bearings but without drives.
- End supports, if applicable
- Shared supports, if applicable.

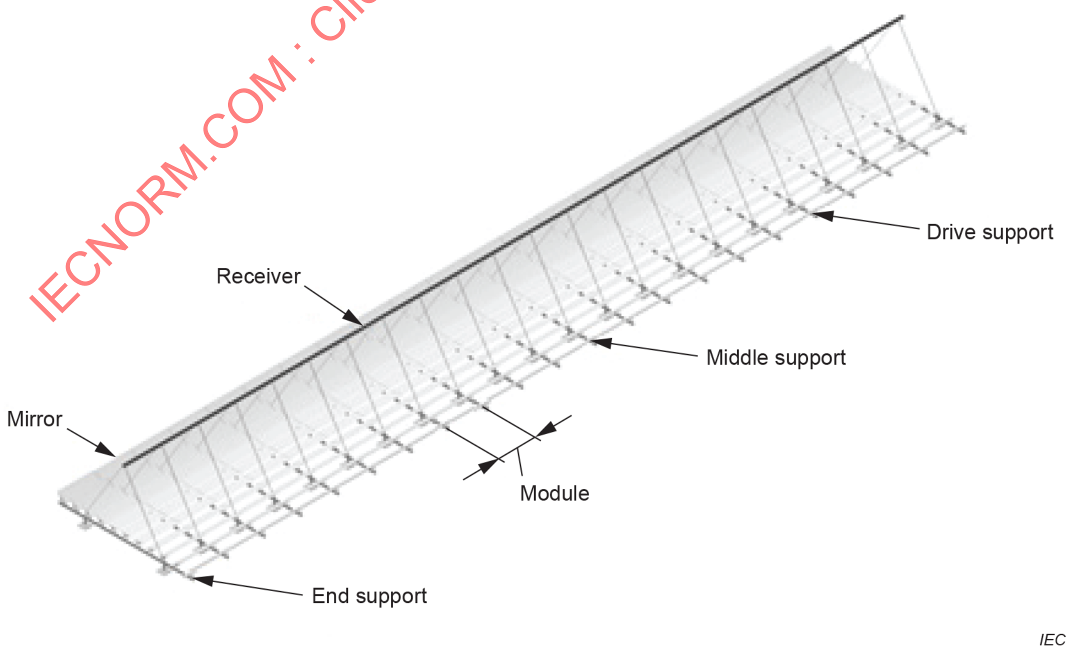


Figure A.1 – General view of a north-south axis Fresnel collector

The basic characteristics of a linear Fresnel collector are detailed below:

- Focal distance or curvature for each mirror row (may be identical for several or all rows)
- Aperture width of the receiver
- Number of modules per collector
- Module and collector length
- Number of reflector rows per module/collector
- Receiver tubes per module/collector
- Max operational wind speed
- Max survival wind speed.

The geometrical relation between receiver structure and mirror support structure may also be asymmetric. The rotational axes of the mirror rows usually are in a plane, but also a varying height from ground for every mirror row has been considered. The receiver usually is centered above the mirror field attributed to the receiver (Figure A.1), however, there are configurations with receivers on one side of the mirror field (Figure A.2), or mirror fields able to illuminate different neighbouring receivers (compact linear Fresnel reflector).

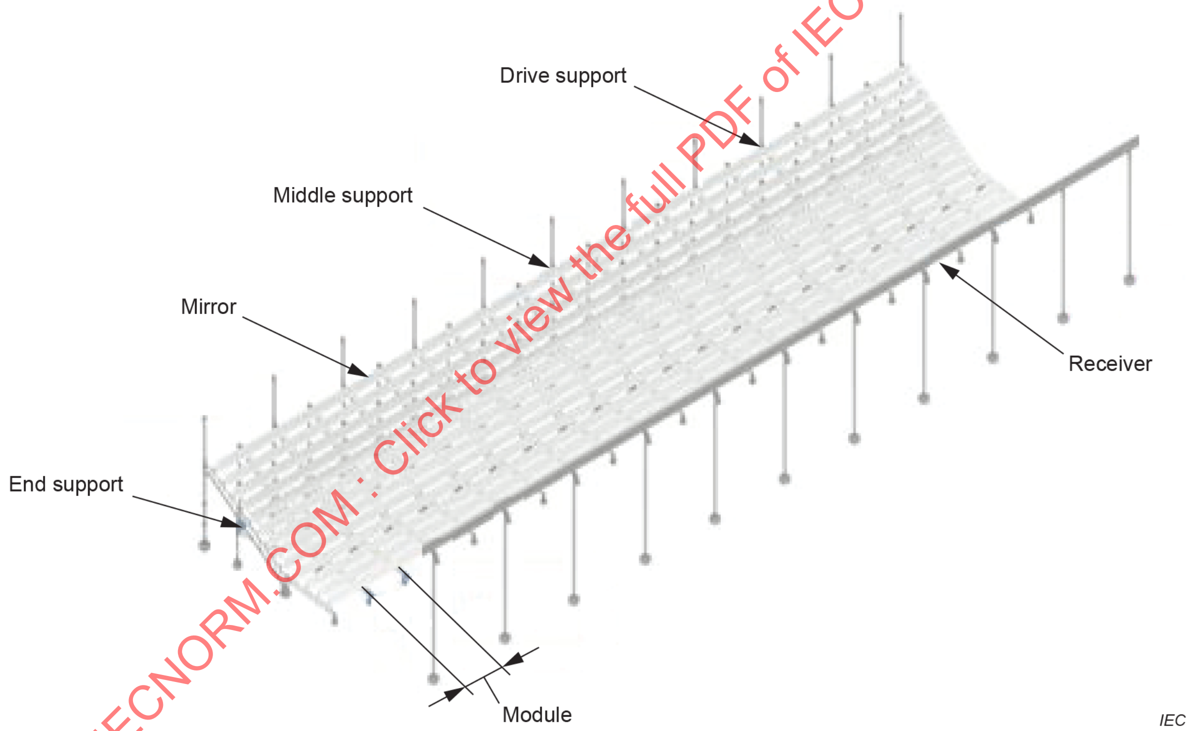


Figure A.2 – General view of an asymmetric east-west axis Fresnel collector

The collector is basically formed by the following elements.

A.1.2 Collector row structure

In general one collector row consists of a primary reflector field and a linear receiver tower structure. However, there are configurations where primary reflectors (see A.1.4) may redirect the sunlight towards two different (neighbouring) receivers (see A.1.7), depending on the rotational position.

The bearing structure of the primary reflector field has the function to support the primary reflectors, provide the final linear Fresnel surface, and assure their right position to track the sun. It has the adequate strength to withstand external loads, and high stiffness to provide good optical performance.

The bearing structure of a linear receiver tower holds a receiver above the primary reflector field at a fixed position. It has the adequate strength to withstand external loads, and keep the focal position in order to provide good optical performance.

In general, the bearing structure of a module consists of a main body, which holds the many rotational axes of the primary reflectors. On the rotational axis of each mirror row in a module the primary reflectors have to be fixed via a support structure. The fixing of the mirror material depends on the material itself (stiffness, fragility etc.) and may be done by clamping, screwing, glueing or other methods. Details are given in A.1.5.

A.1.3 Support structure and foundation

The bearing structure of the linear receivers shall hold the position of the receiver fixed with respect to the primary mirror field, however it shall minimize the shadow on the mirrors. Therefore stiff but light-weight structures are preferred. Metallic beams, steel cables or ropes may be used for the construction. The receiver tower construction should take into account the thermal expansion of the receiver tube(s).

The supports of the mirror rows are designed to support the axis of rotation (shaft) of the modules.

- Middle supports are situated between two modules that belong to the same linear Fresnel collector.
- Shared supports are situated between two modules that belong to different linear Fresnel collectors.
- End supports are situated at the end of the linear Fresnel collectors.

A.1.4 Primary reflectors

The reflector facet is the element reflecting the solar radiation onto the receiver tubes. It shall have high precision, high specular reflectance and high durability.

Reflector facets are arranged in parallel rows; these rows make the primary reflectors. All the facets of a given row shall be installed to have their surface parallel to the same plane. During the tracking each row is suitably oriented to reflects the solar radiation onto the receiver.

The reflector facets can be shaped as parabolic reflectors, which are directly manufactured with the appropriate curvature for a specific design of linear Fresnel collector, i.e. with the dimensions and focal distance for a specific geometry, or can be produced as flat mirrors and later suitably curved during the installation in the of the whole linear Fresnel collector.

The reflectors can be silver coated glass reflectors or can be of alternative reflector materials.

A.1.5 Mirror support

A good mirror support is important as otherwise the mirror shape may be distorted by wind and gravity forces. There are different ways to support and hold mirrors (depending on the material). The support may also be utilized to define or stabilize the slight mirror curvature which is needed to focus on the receiver aperture.

The main function of the mirror support is to hold the mirrors of a primary reflector, while ensuring the transmission of motion from the tracking system to the primary reflector mirror rows, in order for these to be in their intended position. In certain designs, in particular where the shape of the mirrors is obtained through mechanical bending, an additional function of the mirror support can be to maintain the mirrors in their intended optical shape.

The mirror support shall have the adequate strength to withstand external loads, according to the applicable local construction codes and standards. It shall also display a high stiffness, in order to minimize torsion and bending associated with both external (gravity, wind) and internal (mirror bending reaction, in case of mechanically bent mirrors) loads. Particular attention shall be paid to designing the bonding interface with the mirrors, which shall allow a safe differential thermal expansion between the mirror support and mirrors, to be calculated based on the site-specific extreme temperature conditions.

Primary reflector mirror supports typically include a core, an interface with the mirrors (bonding material, such as an adhesive) and connections to the tracking system (generally flanges). There are several design alternatives for the core, which fall into either the single-part or multiple-parts categories. In the single-part design, the main body, which typically consists of a closed box, is used directly for bonding the mirrors to the mirror support. In the multiple-parts design, the main body, which is typically a torque tube or a space frame, is assembled to one or several holders (cantilever arms for torque tube structures and metallic struts for space frame structures), on which the mirrors are bonded. The core is generally made of steel, aluminum, polymers or other materials or material combinations.

A.1.6 Mirror drives

In a linear Fresnel collector the rotational horizontal axes of the individual primary reflector rows rotate in order to focus the light from the moving sun to the fixed receiver position. The drive(s) can be individual for each mirror row, for neighbouring groups of rows or for all rows coupled to each other, as the angular speed of each mirror row is the same (Figure A.3). Also one single drive can be used for a module or even several modules when the axes are coupled. The rotational movement may be created either by hydraulic drives or electrical gear units. In the case of hydraulic units it usually has the two hydraulic cylinders, but also a hydraulic group, electrovalves, deposit, filter and other actuation elements.

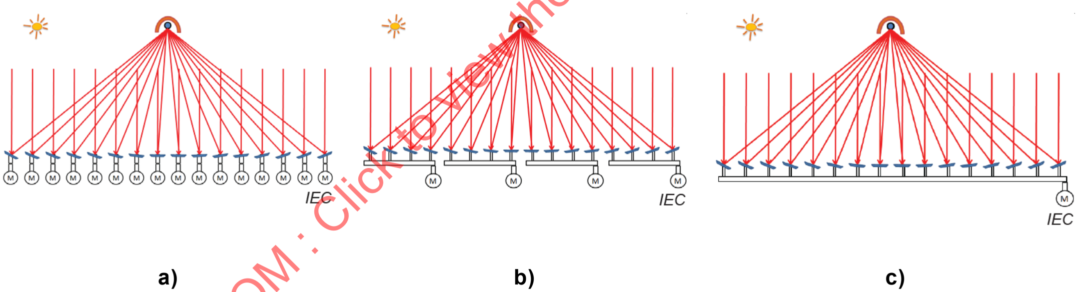


Figure A.3 – Schematic drawing of individual drive a), group drive b) and field drive c) options

A.1.7 Receiver

The receiver is composed of one or more receiver tubes and in most cases of a receiver cavity.

A.1.8 Receiver tube

In Linear Fresnel CSP system, one or more receiver tube(s) are fixed to the receiver cavity structure and installed along the focal area of the primary reflectors (for no secondary concentrator) or along the focal area of the secondary concentrator, to absorb the solar radiation which is reflected onto its surface, then convert it to heat which is transferred to the HTF by means of heat conductivity and convective heat transfer. The heated HTF is pumped to a heat exchanger to generate steam used for electricity production. Due to the concentrator design of a Fresnel collector, the receiver tubes are stationary in contrast to parabolic trough receiver tubes which are movable with solar position. Therefore they can be easier adapted to the different types of heat transfer medium, including water, oil, molten salt and so on.

The receiver tubes can be summarized into two types:

a) Evacuated receiver tube

This receiver tube consists of an inner metallic tube (usually made of stainless steel), an outer glass tube (glass envelope) and metallic expansion bellows on both sides, which form the joint between the inner metallic tube and the outer glass tube with an annulus between inner metallic tube and outer glass cover tube which is evacuated before delivery to reduce heat losses under high temperature. A long-acting getter will be installed into the annulus to maintain the vacuum to a certain level, where the vacuum indicator indicates whether the vacuum is intact by the color changing of an indicator spot. The inner tube is covered by a selective coating to maximize the absorptance of the concentrated radiation and minimize the re-radiation of the infrared radiation (thermal emittance). The glass envelope on both ends is joined with the metallic bellows by a sophisticated glass-to-metal seal, resistant to operating temperatures and sealing the enclosed vacuum. On the other side, the metallic bellows are welded to the inner receiver tubes. The elasticity of these connecting bellows compensates the difference of the thermal expansion of the inner metallic and the outer glass envelope during warming up and cooling down of the receiver tubes. The sensitive glass-to-metal seal is protected from damage due to overheating by solar radiation by a sleeve called bellow shield.

The energy of the concentrated radiation is converted into thermal energy at the absorber surface of the inner metallic tube, which transfers the circulating heat transfer fluid and heats it up. The glass envelope works as an additional barrier to the infrared re-radiation and reduces thermal losses like a greenhouse made of glass. It is usually covered by an antireflective coating.

b) Non-evacuated receiver tube

This is just a metallic tube with a selective coating which is special designed and suitable for air conditions to maximize the absorptance of the concentrated radiation and minimize the re-radiation of the infrared radiation (thermal emittance).

Consideration should be given to the stability of the coating in air while achieving high surface temperatures (depending on the HTF and the operational parameters used).

NOTE Even non-evacuated receiver tubes may be contained in an outer glass tube (glass envelope).

A.1.9 Receiver cavity

a) Single tube receiver cavity with secondary reflector and glass cover (Figure A.4)

The main function of this receiver cavity is to re-concentrate solar radiation from primary reflectors onto the receiver tubes, to achieve this, a compound parabolic curved reflector or any other suitable secondary concentrator will be formed by pre-anodized and PVD-coated aluminum or a suitably shaped glass mirror. In addition, silver coated glass mirrors can also be formed as curved reflectors. A glass cover will be installed when equipped with a non-evacuated receiver tube to minimize the heat losses.

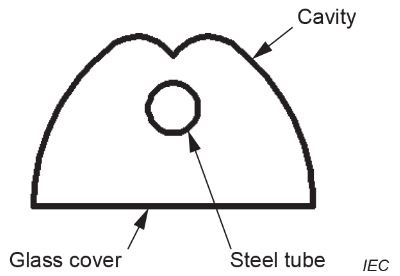


Figure A.4 – Typical receiver cavity with secondary reflector and glass cover

b) Single tube receiver cavity with secondary reflector and without glass cover (Figure A.5)

This receiver cavity is similar to the aforementioned one in item a). However due to the use of an evacuated receiver tube, a glass cover is not needed.

Instead of an evacuated receiver also a non-evacuated receiver tube plus glass envelope can be used.

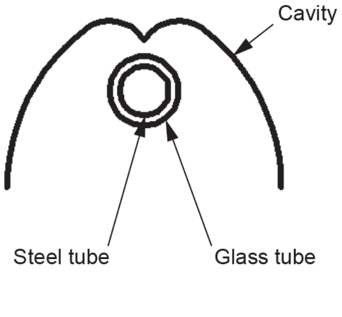


Figure A.5 – Typical receiver cavity with secondary reflector and without glass cover

c) Receiver cavity with parallel tubes (Figure A.6)

Multiple small diameter non-evacuated receiver tubes are fixed parallel along the focal line. An insulated cavity and a glass cover will be used to minimize the heat losses. The multi-tube concept allows also to circulate HTF in two directions through the cavity, thus allowing also one-sided connection of inlet and outlet.

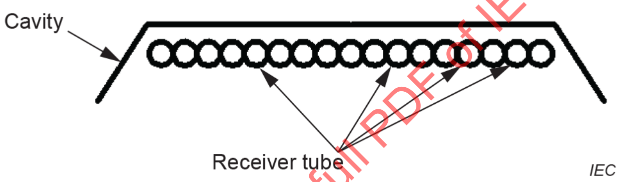


Figure A.6 – Typical receiver cavity with multiple parallel tubes

NOTE Other options for receiver geometries as the ones described in A.1.9 may be possible.

A.1.10 Receiver support and casing

The receiver cavity preferably should be constructed in a way that the receiver tubes can move / slide freely due to thermal expansion.

Heat loss shall be minimized considering economics and cost, balanced by the overheating limit of the secondary reflector. Therefore for non-evacuated receivers thermal insulation, suitable for operational temperatures, may be used to reduce convective and radiative heat losses of the cavity walls. In order to protect insulation against the environment, a solid casing on the backside of the cavity may be used. Evacuated tubes do not require thermal insulation in the cavity walls.

The receiver cavity including receiver tube(s) and – if applicable - insulation casing has to be fixed in a support construction which guarantees little vibrations under wind conditions which are considered suitable for operation.

A.1.11 Tracking system

The mirror rows of a linear Fresnel collector have to track the sun to reach a continuous concentration of the direct solar irradiance on the receiver tubes from sunrise to sunset.

The linear Fresnel collector is a line-focus solar collector and has a one-axis tracking system. Each mirror row rotates during its daily tracking of the sun around its rotation axis driven by a drive unit or actuator composed of hydraulic actuators or electric gear drives which move the bearing structure carrying the primary reflectors. Not every row needs an individual actuator. Mechanical coupling between groups of mirror rows is possible and reduces the number of costly actuators. This mechanical coupling, e.g. may be a movable rod coupled to the individual rows, which is driven horizontally by one actuator, or a toothed belt connected to cogwheels or gearboxes in each row.

The tracking is controlled by a local controller, which needs information about the sun position. This information is usually calculated with a mathematical algorithm that calculates the sun position very accurately.

The sun position is compared to the mirror row axis position and any difference is corrected using the drive unit. It is also possible to use sun sensors composed of lens and photocells to check and optimize the focal image position on the receiver aperture.

A.2 Operation modes

There are different operation modes of the linear Fresnel collector when it is installed in a solar field. The basic operation modes are:

– Track position: position of the collector mirror rows when every row is focused, i.e. when each row is tracking the sun and the concentrated solar radiation is impinging on the receiver.

– Stow position: rest or defense position of the collector. It is the mirror row positions that the collector has during night, when the solar field is not running, or when there are strong wind conditions.

– De-steer (Defocusing) position: position of the collector when is tracking the sun but partially defocused, so the concentrated solar radiation is not impinging on the receiver.

– Partial tracking: the thermal power of linear Fresnel collectors with individual or group control of mirror row tracking may be changed from 100 % to intermediate levels, depending on how many mirror rows are focused onto the receiver and how many are defocused.

Annex B
(normative)

Documentation to be supplied by the collector manufacturer

B.1 General configuration of the linear Fresnel collector

B.1.1 Model and manufacturer

B.1.2 Axes and movements

- Possible range of orientation of the collector axis: (N/S – E/W) (only if the mechanism is meant to be in both orientation)
- Tracking: (E/W – N/S)
- Maximum tilt angles of mirrors (º)
- Maximum and minimum tracking angles [º].

B.1.3 Collector grouping

- Number of collectors per loop.

B.2 Geometric characterization of the linear Fresnel collector

- Geometric concentration ratio [-]
- Acceptance angle of secondary concentrator (if applicable) [º]
- Curvature radius [m] for each mirror rows
- Length of the linear Fresnel collector [m]
- Aperture width of the linear Fresnel collector [m]
- Gross aperture area [m^2]
- Height of the mirror row rotation axes above ground [m]
- Number of modules
- Module length [m]
- Number of facets (reflectors) per module
- Reflector facet type
- Aperture width of receiver cavity [m]
- Height of receiver cavity aperture plane above mirror axis plane [m]
- Number of receiver tubes per module
- Receiver tube length [m]
- Active length of receiver [m]
- Outer diameter of the glass tube [m] (if applicable)
- Inner diameter of the glass tube [m] (if applicable)
- Cover glass width [m] (if applicable)
- Outer diameter of the receiver tube (metallic tube) [m]
- Inner diameter of the receiver tube (metallic tube) [m].

B.3 Mechanical characterization of the linear Fresnel collector

- Total dead load including reflectors and tubes [kg]
- Total specific weight per collector gross area [kg/m^2].

B.4 Optical characterization of the linear Fresnel collector

- Design / simulation peak optical performance (θ=0º)
- Self-shading factor (including self-shading of receiver)
- Design / simulation transversal and longitudinal incident angle modifier function.

B.5 Description of linear Fresnel collector operating modes

B.5.1 Design operating conditions

- Heat transfer fluid temperature range (ºC)
- Design temperature (°C) and pressure (bar)
- Heat transfer fluid type (oil/molten salt/water).

B.5.2 Normal operating conditions

- Wind speeds [m/s]
- Temperature range [ºC].

B.5.3 Reduced weather/geological operating conditions (features to be reduced shall be defined (optical, thermal performance) and how much they are reduced)

- Wind speeds [m/s]
- Temperature [ºC].

B.5.4 Stow conditions

- Wind speed [m/s].

B.5.5 Survival conditions

- Wind speed [m/s]
- Load for each support
- Temperature [ºC]
- Seismic activity
- Weather (rain, sand, snow and thunder storms).

B.6 Optical and tracking accuracy

B.6.1 Accuracy under normal operating conditions

B.6.2 Accuracy under reduced operating conditions

B.7 Linear Fresnel collector component information

B.7.1 Linear Fresnel collector structure

- Types / structural elements
- Materials
- Specific weight of structure [kg/m^2]
- Specific weight [kg/m^2]
- Dimensions [m]
- Testing certificates on structural stability.

B.7.2 Receiver tube

- Types
- active length [m]
- Absorber tube
  - Material
  - Absorptance and emittance (θ=0°) [-]
  - Type of vacuum
- Glass cover tube
  - Types
  - Material
  - Anti-reflective treatment
  - Transmittance (θ=0°)
- Testing certificates.

B.7.3 Receiver cavity

- Geometry
- Self-shading factor (of primary mirror field)
- Casing material
- Insulation material (if applicable)
- Secondary reflector material (if applicable)
- Inner casing material and colour (if applicable)
- Cover glass (if applicable)
- Testing.

B.7.4 Primary and secondary reflectors

- Geometric specifications
- Solar weighted reflectance
- Specular reflectance
- Durability
- Optical quality
- Testing.

B.7.5 Drive mechanism

- Type (hydraulic, electric)
- Individual, group or collector coupling of drives
- Reduction rate
- Accuracy
- Rigidity
- Power supply
- Power consumption
- Stowing times
- Durability
- Blocking system
- Testing.