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IEC 62862-3-2

Edition 1.0 2018-07

INTERNATIONAL STANDARD

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colour inside

Solar thermal electric plants –
Part 3-2: Systems and components – General requirements and test methods for large-size parabolic-trough collectors

Centrales électriques solaires thermodynamiques –
Partie 3-2: Systèmes et composants – Exigences générales et méthodes d'essai des capteurs cylindro-paraboliques de grande taille

IEC 62862-3-2:2018-07(en-fr)

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SOLAR THERMAL ELECTRIC PLANTS –

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FOREWORD

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

FDIS	Report on voting
117/87/FDIS	117/89/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,
- replaced by a revised edition, or
- amended.

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SOLAR THERMAL ELECTRIC PLANTS –

Part 3-2: Systems and components – General requirements and test methods for large-size parabolic-trough collectors

1 Scope

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

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

This document applies to parabolic-trough collectors equipped with the manufacturer-supplied sun tracking mechanism.

The test method in this document does not apply to any collector under operating conditions where phase-change of the fluid occurs.

This document applies to the whole collector.

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 – Terminology*

ISO 9488:1999, *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 and IEC 62862-1-1 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

The following symbols are used in this document:

β_{real}	elevation (measured by an inclinometer) (°)
ρ_{test}	reflectance measured during the test (-)
ρ_{nom}	reference value of the reflectance of the reflectors installed in the collector (-)
θ_T	tracker elevation error (°)
F_c	ratio between the product of the reflectors' reflectance and the glass envelope transmittance during the test and the product of the reflectance and transmittance nominal values
$\chi_{reflector}$	ratio between the measured specular reflectance of reflector to the nominal specular reflectance of reflector

4 Test requirements

The parabolic-trough collector should be equipped with all the components supplied by the manufacturer (such as bearing structure, reflector facets, receiver tubes, actuator system and control) and mounted according to the manufacturer's instructions.

The different components/elements (such as the receiver, reflector, tracker, structure) should be previously tested separately by current test methods or standards when available.The documentation to be supplied by the manufacturer shall be according to Annex B.

5 Instrumentation

5.1 Solar radiation measurement

Solar radiation measurement shall be performed according to 21.1 of ISO 9806:2017.

Incidence angles will be determined by calculation or with sun position sensors with an accuracy equal to or higher than ± 0,1°. In the case they are calculated from the sun position equation, the accuracy of the calculation algorithm shall be equal to or higher than 0,025°.

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.

The collector inlet and outlet positions shall be defined by the manufacturer and the temperature sensors shall be installed at no more than 200 mm from this point.

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

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 at a distance from the collector extremity (end pylon as shown in Figure A.1) not higher than 100 m. If there is no wind speed sensor close enough to the meteorological station of the plant, one temporary sensor should be added close to the collector.

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. Accuracy of the inclinometers 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) and another one at one of the collector's end.

6 Test procedure

6.1 Sample description

A general description and requirements of the parabolic-trough collector are given in Annex A. The collector description should be supplied by the manufacturer according to Annex B.

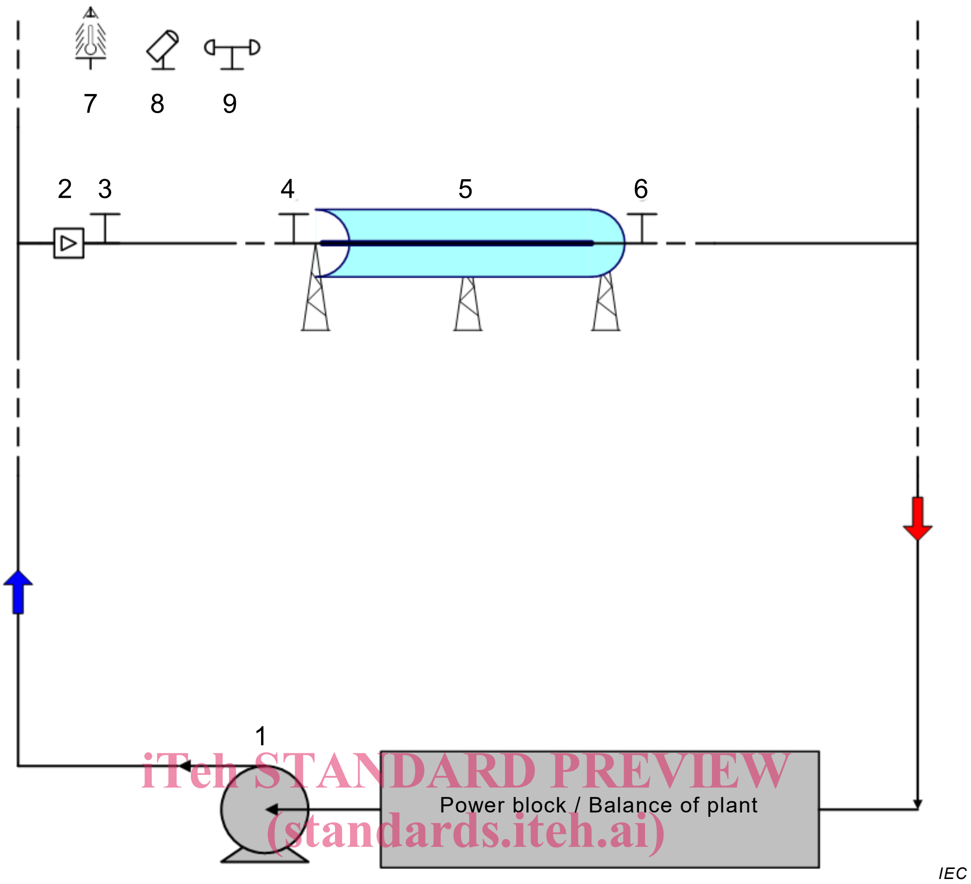
All the components of the tested collector (reflectors, receiver, structure, etc.) shall be representative of the product. The components shall be selected randomly from the production.

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

6.2 Test equipment (installation/mounting/cleanliness)

6.2.1 Performance test

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



Key

1 pump
2 flow meter (test)
3 temperature sensor
4 temperature sensor (t_{in})
5 parabolic-trough collector unit
6 temperature sensor (t_{out})
7 ambient temperature sensor (t_a)
8 pyrheliometer
9 anemometer

Figure 1 – Test equipment installation

During the tests of a parabolic-trough collector it will be necessary to guarantee that the reflectors and glass envelopes of the receivers are kept clean. It shall be ensured that the collector's cleanliness factor is within the range 0,95 < F_c < 1,0. For testing purposes, the cleanliness factor is defined as the ratio between the product of the reflectors reflectance and the glass envelope transmittance during the test and the product of the reflectance and transmittance nominal values.

There is currently no field instrumentation available to determine the degree of dirt in the receiver cover once installed in the collector; a good approach is to assume that the same percentage of reduction in the reflectors reflectance and in transmittance of the glass envelope is produced due to dirt. The reflectors cleanliness factor $\chi_{reflector}$ will be measured with a portable reflectometer in each sequence of the test, at least in five positions per module. The number and position of points measured should be reported in the test report. If the mean cleanliness factor is lower than 0,95, the collector (both reflectors and glass tube) should be cleaned.

Therefore, the global cleanliness is given by Equation (1):

$$F_{C} = \left(\chi_{reflector}\right)^{1,5} = \left(\frac{\rho_{test}}{\rho_{nom}}\right)^{3/2} \tag{1}$$

where ρ_{test} is the specular reflectance measured during the test and ρ_{nom} is the reference value of the specular reflectance of the reflectors installed in the collector.

ρ_{nom} and ρ_{test} should be measured with the same equipment.

6.2.2 Tracking error test

The solar tracker should be installed according to the manufacturer's recommendations. The collector should have all the necessary components (receiver tube, reflector, structure, etc.).

One inclinometer or other angular sensor should be mounted on the centre of the parabola or on the reflector, close to the drive pylon.

The minimum number of measurement devices is two, one close to the drive pylon and one mounted in the collector end. It is recommended to install an additional sensor in the other collector end. If the sensor is not perfectly parallel to the concentrator aperture an offset should be subtracted to the tracking error calculated.

6.3 Measurement procedure

6.3.1 Performance test

The thermal performance test to determine peak optical efficiency, heat losses and incidence angle modifier shall be performed according to ISO 9806:2017 using the quasi-dynamic test method. The wind speed shall be less than 5,5 m/s for each point measured.

6.3.2 Tracking error test

The tracking test is performed over the full available tracking range (e.g. from sunrise to sunset), by manually set tracking angles in steps of 10 degrees. The data shall be recorded and evaluated for all the steps. Deviations between measured values and set values at the drive have to be analysed. Also deviation between measured values at collector end and collector centre have to be analysed. The recorded data should include:

- the tracker elevation error recorded in 1 min average intervals and calculated as Equation (2):

  $$\theta_{T} = \beta - \beta_{set} \tag{2}$$

  with the set tracking angles β_{set} and the real β (measured with an inclinometer);
- direct normal irradiance (DNI) recorded in 1 min average intervals (only if tracking system with sun sensor);
- wind speed reported in 1 min increments for the 10 min mean speed at 10 m height (terrain for the wind measurement and tracker location shall have a slope of less than 3 %);
- date and time.

The date and location of the test should be reported to facilitate assessment of adequacy of the data collection, particularly with respect to the range of motion.

6.4 Calculation and test results

6.4.1 General

Calculation of the test results shall be performed according to Clause 24 of ISO 9806:2017 for the quasi-dynamic test method.

The increase of specific enthalpy of the fluid 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.

It is not recommended to use the specific heat capacity, because it depends on both inlet and outlet temperature.

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 or any other independent body. This data shall be perfectly documented and referenced.

6.4.2 Useful power

The model of the collector should be according to Formula (13) from ISO 9806:2017. Additional requirements are set for collectors with a transparent cover and a concentration ratio higher than 3, or for evacuated concentrating collectors: the wind speed dependency can be neglected. So, some parameters (a_3, a_6 and a_7) may be set to 0.

Additionally, for collectors with a concentration ratio higher than 20, the parameters a_4 and K_d may also be set to 0. In this case the collector model would be given by Equation (3) or Equation (4) assuming that with a good tracking, θ_T = 0°.

$$\dot{Q} = \dot{m}\,\Delta h = A_G \left(\eta_{0,b} K_b(\theta_L) G_b F_C - a_1 (t_m - t_a) - a_8 (t_m - t_a)^4 - a_5 \, {dt_m}/{dt} \right) \quad (3)$$

$$\dot{Q} = \dot{m}\,\Delta h = A_G \left(\eta_{0,b} K_b(\theta_L) G_b F_C - a_1 (t_m - t_a) - a_2 (t_m - t_a)^2 - a_5 \, {dt_m}/{dt} \right) \quad (4)$$

A_G: should be the solar collector gross aperture area (see definition in IEC TS 62862-1-1), as shown in Figure 2. $A_G = L \times W \times N$, where L and W are the gross length and width and N is the number of modules, respectively.

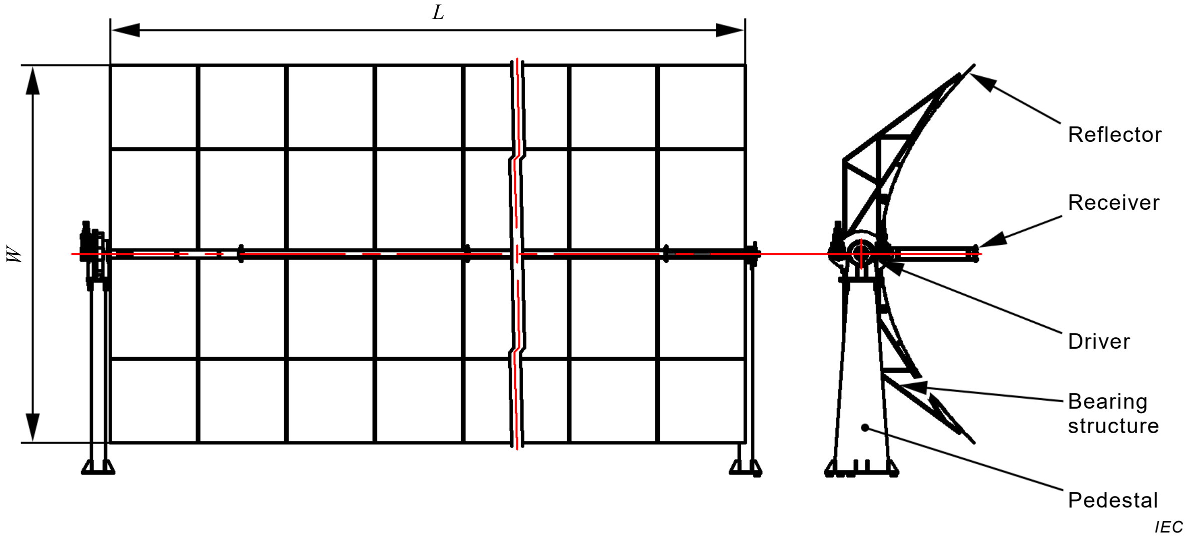


Figure 2 – Structure sketch of one module of parabolic-trough collector – Gross aperture area definition

Equation (3) will be preferred, with a_8 parameter for heat losses. If the r^2 of the regression is better with Equation (4), and the t-ratio (parameter value/standard deviation of parameter) of the a_8 parameter is less than 3, then Equation (4) will be used, with a_2 parameter for heat losses.

6.4.3 Incidence angle modifier (IAM)

When the incidence angle is different from 0° ($\theta_L \neq 0°$), the value of the incidence angle modifier, $K(\theta)$, is obtained from Equation (5). The set of values $K(\theta)$ obtained as a function of the different incidence angles θ shall be set to a curve type such as:

$$K(\theta) = 1 - \frac{b_1 \cdot \theta + b_2 \cdot \theta^2 + \ldots + b_n \cdot \theta^n}{\cos(\theta)} \qquad (5)$$

where parameters b_1, b_2 and b_n will be determined by least-square fitting.

NOTE In general a quadratic or cubic polynomial is adequate.

6.4.4 Validation performance test

6.4.4.1 Power output

The test consists in keeping the collector in operation for two days (for at least four hours, two hours before noon and two hours after noon) at two different fluid inlet temperatures, T_{in}, (different by at least 10 K) with the daily average environment ambient temperature different from no more than 5 °C and steady within the normal working temperature range of the collector, with the transversal incidence angle at θ_T = (0 ± 0,1)° and the longitudinal incidence angle varying during the whole day.

Stability of the measurements and other requirements of the global efficiency test will be the same as in the thermal performance test.

To validate the former characterization, the useful power output from the collector shall be calculated according to Equation (3) or Equation (4) considering the determined parameters.

The average difference between the calculated and measured power should be within ± 5 %.

6.4.4.2 Peak optical efficiency (optional)

The peak optical efficiency should be calculated theoretically using the intercept factor measured by deflectometry, close-range photogrammetry, or other techniques, and the optical properties provided from the receiver and reflectors manufacturers (transmittance of glass cover, absorptance of receiver tube and reflectance of the reflector).

The formula to calculate the peak optical efficiency from the solar components manufacturers specifications is:

$$\eta_{opt,0°} = \rho \cdot \gamma_{T,0°} \cdot \tau \cdot \alpha \tag{6}$$

Where ρ is the near-normal reflectors solar reflectance, $\gamma_{T,0°}$ is the near-normal overall intercept factor, which is the product of the intercept factor of the solar concentrator γ_C and the effective length factor of the receiver tubes installed in the parabolic-trough collector γ_R; τ is the near-normal transmittance of the receiver glass envelope, and α is the near-normal absorptance of the receiver metallic tube.

The difference between the determined optical efficiency (Equation (3) or Equation (4)) and measured (Equation (6)) should be within ± 5 %. If the difference is higher, at least the test results, data provided by the manufacturers of the single components and the overall intercept factor measurements should be analysed and reported.

6.4.5 Tracking error test

6.4.5.1 Data binning by wind speed

If necessary, 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.

6.4.5.2 Data quantity

For each of the data sets (“low wind, minimum error measurement”, “high wind, maximum error measurement”, and so on), ensure there are a sufficient number of data points.

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

- at least 360 data points after the above filtering;
- at least five separate days, with at least 50 data points per day;
- at least 180 points at high wind speed;
- at least 50 data points before noon and 50 points after noon.