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TECHNICAL SPECIFICATION

colour inside

Solar thermal electric plants – Part 2-1: Thermal energy storage systems – Characterization of active, sensible systems for direct and indirect configurations

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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SOLAR THERMAL ELECTRIC PLANTS –

Part 2-1: Thermal energy storage systems – Characterization of active, sensible systems for direct and indirect configurations

FOREWORD

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IEC TS 62862-2-1 has been prepared by IEC technical committee 117: Solar thermal electric plants. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft TS	Report on voting
117/119/DTS	117/127/RVDTS

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 Technical Specification 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 "http://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- withdrawn,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
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

IEC TC 117 prepares International Standards (and other types of documents) for systems of solar thermal electric (STE) plants for the conversion of solar thermal energy into electrical energy and for all the elements (including all sub-systems and components) in the entire STE energy system. These documents would cover all current different types of systems in the STE field, as follows:

- Parabolic trough
- Solar tower
- Linear fresnel collectors
- Parabolic dish
- Any other type of system using thermal storage that is not connected to the grid.

The documents define terminology, design and installation requirements, performance measurement techniques and test methods, safety requirements, and "power quality" issues for each of the above systems.

In addition to those systems, there are several major components that require standardization, such as the storage media (oil, molten salt, ceramic, concrete, etc.).

SOLAR THERMAL ELECTRIC PLANTS –

Part 2-1: Thermal energy storage systems – Characterization of active, sensible systems for direct and indirect configurations

1 Scope

This document defines the requirements and the test methods for the characterization of thermal energy storage (TES) systems.

This document contains the information necessary for determining the performance and functional characteristics of active direct and indirect thermal energy storage systems based on sensible heat in solar thermal power plants using parabolic-trough collector, Fresnel collector or tower central receiver technology with liquid storage media.

This document includes characterization procedures for testing energy storage system charge and discharge, as well as reporting the results. Test performance requirements are given and the instrumentation necessary for them, as well as data acquisition and processing methods and methods for calculating the results and their uncertainties.

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 62862-1-1:2018, *Solar thermal electric plants – Part 1-1: Terminology*

IEC 60584-1:2013, *Thermocouples – Part 1: EMF specifications and tolerances*

IEC 60751:2008, *Industrial platinum resistance thermometers and platinum temperature sensors*

ISO 5725-3, *Accuracy (trueness and precision) of measurement methods and results – Part 3: Intermediate measures of the precision of a standard measurement method*

ISO 5725-6, *Accuracy (trueness and precision) of measurement methods and results – Part 6: Use in practice of accuracy values*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 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

4 Symbols and abbreviated terms

The symbols, units, subscripts, superscripts, and abbreviated terms shown in Table 1 and Table 2 are used in this document.

Table 1 – List of symbols and units

Name	Symbol	Units	Observations
Confidence level		%	
Coverage factor	FC	-	dimensionless
Critical range factor	$f(n)$	-	dimensionless
Energy	E	J or Wh	
Mass flow rate	$\dot{m}$	kg/s	
Performance	Ƞ	%	
Power	P	W	
Storage capacity	φ	J or Wh	
Storage level		%	
Temperature	T	°C or K	
Time	t	s	
Uncertainty	s		The units are those of the variable to which the uncertainty refers
Velocity	v	m/s	
Volumetric flow rate	$\dot{V}$ or Q	m^3/s	

Table 2 – List of subscripts, superscripts and abbreviated terms

Script	Meaning
*	Instantaneous value
AMB	Ambient
C	Charge
D	Discharge
DCS	Distributed control system
E	Electrical
HTF	Heat transfer fluid
i, j, k	Numbering value
IN	Inlet
OUT	Outlet
M, N	Number of data recorded or representative
MSF	Molten salt fluid
Q	Flow meter number
RTD	Resistance temperature detector
T	Thermal
TES	Thermal energy storage

5 Thermal energy storage (TES) systems

5.1 Classification of TES systems

Thermal storage can be classified according to several different criteria:

- Thermal energy storage mode: thermal energy supplied by the solar field may be stored as sensible heat, latent heat, reaction heat or a combination of them.
- Circulation of the storage medium: TES systems can be classified as active or passive.
- System configuration: thermal energy storage systems may be direct or indirect.

For more details regarding the types of TES systems, refer to Annex A.

5.2 TES systems covered by this document

This document covers active sensible two-tank direct and indirect thermal storage systems using "molten salt"[1] as the storage media. The term "molten salt" shall be considered synonymous with "solar salt" in any part of this document. Furthermore, in the case of direct storage, molten salts are also used as the HTF.

5.3 TES system limits

The boundary limits of the different TES systems covered in this document are described below.

In the case of indirect systems:

a) the limit is the inlet at the HTF side of the heat exchanger between the HTF and molten salt.

b) the limit is the outlet at the HTF side of the heat exchanger between the HTF and molten salt.

In the case of direct systems:

c) the limit is the inlet side of the TES: the inlet at the cold tank and the inlet at the hot tank.

d) the limit is the outlet side of the TES: the outlet at the cold tank and the outlet at the hot tank, when discharging the TES.

Refer to 7.4 for the system boundaries diagrams.

5.4 Key components

All the following types of equipment, at a minimum, are considered as key components of the thermal energy storage system:

- storage medium,
- storage tanks,
- piping,
- heat exchangers (in the case of indirect storage systems),
- electrical system,
- control systems,
- safety systems,
- pumps and valves,
- instrumentation: pressure gauges, thermocouples, flow meters, level gauges.

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1 The description of "molten salt" is provided in Annex B.

For more details regarding the components of a TES system, refer to Annex B.

The documentation that should be provided by the TES manufacturer/supplier is given in Annex D.

6 Instrumentation and measurement methods

6.1 General

The following measurements in this Clause 6 shall be taken and recorded during testing.

6.2 Flow rate measurements

The flow meter to be used for the flow rate measurement should provide Type B uncertainty below 1 % in flow rate measurements within the heat transfer fluid working temperature range.

During instrument installation, special attention should be given to all the requirements for ensuring proper equipment functioning (e.g., respecting the length of straight sections upstream and downstream from the flow meter, what direction the sensor should be facing, etc.), which shall be defined by the supplier.

When the flow meter measures the volumetric flow rate in m^3/s, the density of the heat transfer fluid, which is a function of temperature, shall be calculated. For this, a temperature sensor is installed as close as possible to the flow meter, but without preventing it from working properly.

The instantaneous volumetric flow rate of the heat transfer fluid $\dot{V}$ or Q^* which feeds the storage system in time t is measured in m^3/s.

For reliable measurement, at least two independent flow meters are required, located at the inlet and outlet of the storage system. Furthermore, the minimal installation conditions required by the manufacturer should be respected.

Flow rate measurement treatment shall be performed according to Clause C.1.

6.3 Temperature measurements

6.3.1 Heat transfer fluid temperatures

The instantaneous temperatures of the heat transfer fluid are measured at time t, at a maximum distance of 5 m from the inlet or outlet of the test boundary. If this is not possible, they are measured at the closest point to the inlet or outlet of the test boundary. These temperatures may be given by any temperature measurement device, thermocouple or RTD, as long as the sensor part of the device is well within the fluid and is resistant to its contact, or, alternatively, the sensor is within the thermowell, and is also well within the fluid and is in contact with the inner wall which enables it to be read correctly. For long connection lengths to the measurement point, an analogical-digital conversion protocol is recommended.

Instantaneous data shall be recorded by the data acquisition system for a period of less than 1 min. At least three independent sensors are required at the inlet and as many at the outlet, so there are at least the required number of instantaneous data series detailed in Clause C.2.

The uncertainties considered in the measurement are those of the measurement sensor, extension and compensating cables, and the data acquisition system device. In the case of thermocouples, the uncertainties shall be of Class 1 in accordance with IEC 60584-1 and Class A in accordance with IEC 60751 for RTDs.

6.3.2 Wall temperatures

Temperature measurements of the external wall of insulation of the hot and cold tank shall be performed to monitor that the external surface temperature does not exceed 55 °C.

The instantaneous temperatures of the external wall are measured continuously at four equidistant points around the tank circumference at least at two different elevations.

The lower elevation shall be at 1,5 m above the platform where the tank is erected. The higher elevation corresponds to the centre of the band that comprises the ¾ portion of the tank height.

These temperatures may be given by any temperature measurement device, thermocouple or RTD.

Instantaneous data shall be recorded by the data acquisition system for a period of less than 1 h.

The uncertainties considered in the measurement are those of the measurement sensor, extension and compensating cables, and the data acquisition system device, that is, Type B uncertainties. The maximum Type B uncertainty allowed in transfer flow temperature is ±1,5 °C.

6.4 Level measurements

The instantaneous level of the heat storage fluid in the hot tank shall be measured continuously. These levels may be given by any continuous level sensors, as long as the sensor part of the device is suitable as regards the fluid and the physical characteristics of the fluid.

Any maximum deviation with respect to nominal values shall be agreed upon by the parties and included in the test procedure. Instantaneous data shall be recorded by the data acquisition system for a period of less than 1 min. At least two independent sensors are required in the hot tank.

The uncertainties considered in the measurement are those of the measurement sensor and the device, that is, Type B uncertainties. The maximum Type B uncertainty allowed in level measurement is ±0,1 m.

6.5 Meteorological signal measurements

6.5.1 Wind speed and direction

Since wind speed and direction affect storage system thermal losses, they shall be measured during testing to determine storage system overall energy and thermal losses. Wind speed is measured by anemometers located at a height no lower than 10 m from the ground, and outside of the range of disturbances caused by adjacent elements. These sensors shall have an uncertainty of ±0,5 m/s or less. If there are several anemometers, the measurement nearest the storage system shall be taken as valid for each record.

For each anemometer, 1 s records shall be used to calculate the mean wind speed during a recording interval of no longer than 10 min.

These measured data records shall be included in the test report and shall be processed as defined in the test procedure.

6.5.2 Ambient temperature

This measurement is only necessary in tests for calculating storage system overall energy and thermal losses.

Maximum Type B uncertainty associated with ambient temperature data recorded by the data acquisition system shall be ±1 °C.

Ambient temperature shall be measured at a position near the storage system, with the sensor protected from nearby heat sources, such as direct solar radiation. It should be especially verified that the sensor position is not within the field of hot air currents caused by gas or vapour emitted by nearby equipment.

The measured data recorded shall be included in the test report and shall be processed as defined in the test procedure.

6.6 Data acquisition

All measured signals shall be (i) recorded by a computer controlled data acquisition system that shall be connected to the DCS of the power plant and (ii) verified with visual readings.

In some extreme conditions where it is not possible to install a temporary computer controlled data acquisition system, data may be recorded manually in suitable form sheets with date and time.

During the test period and when not specified otherwise:

1) the measurements automatically recorded on a computer shall be taken instantaneously, meaning at least every 30 s, and
2) any data collected in writing shall be recorded on data sheets not less than six (6) times per hour, except for flow measurements, which shall be carried out and recorded not less than twelve (12) times per hour. Ambient and wall temperatures should be measured once every hour.

The data collection system shall be designed to:

a) comprise multiple instrument outputs,

e) gather all the necessary data simultaneously, meaning within a maximum interval of 5 s,

f) run any necessary calculations with data collected at the same time, and

g) store data and simulation results.

At all representative operating conditions during each test run, all the DCS screens (showing pressures, temperatures, flows, power, operating status, etc.) shall be printed for inclusion in the test report appendices.

Data collected by temporary test instruments shall be recorded in a dedicated collection system.

All test data (raw and processed data) shall be available.

7 General requirements on tests

7.1 General

Some general requirements for thermal energy storage system characterization testing are defined.

7.2 Test procedure

7.2.1 General

A detailed document about the test plan called the test procedure shall be prepared and approved by the parties involved before testing. This basic document shall include all the details