Madrid, November 17th 2023.

Codification activities with CSP materials

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Materials for Concentrating Solar Thermal Technologies Unit
Plataforma Solar de Almería

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Contents

- CIEMAT - Plataforma solar de Almería
- Introduction to Concentrated Solar Thermal Technologies, Context
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Plataforma Solar de Almería (PSA)

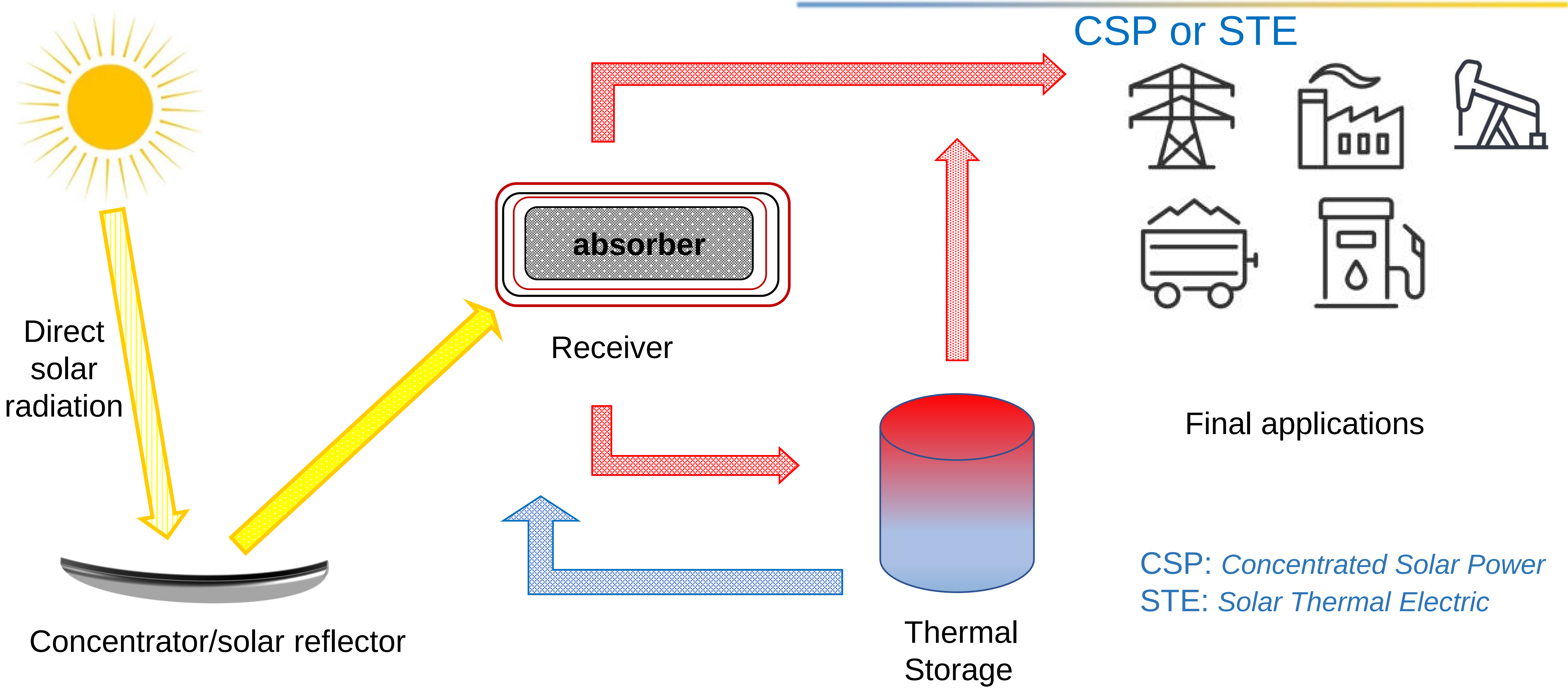
- PSA is a research centre of CIEMAT, integrated in the Energy Department (Almería and Madrid).
- It is the largest centre in Europe and one of the largest in the world, focused on research, testing and development of Concentrating Solar Technologies and its applications
- PSA is formally recognized as Large European Research Installation of Scientific Excellence and ICTS as national level

Plataforma Solar de Almería (PSA)

RESEARCH UNITS

- LINE-FOCUS CONCENTRATING SOLAR THERMAL TECHNOLOGIES UNIT
- POINT-FOCUS CONCENTRATING SOLAR THERMAL TECHNOLOGIES
- MATERIALS FOR CONCENTRATING SOLAR THERMAL TECHNOLOGIES UNIT
- THERMAL ENERGY STORAGE UNIT
- SOLAR PRODUCTION OF FUELS AND COMMODITIES UNIT
- SOLAR THERMAL APPLICATIONS UNIT
- SOLAR TREATMENT OF WATER UNIT

Introduction to Concentrated Solar Thermal Technologies



General Scheme of Concentrating solar thermal (CST) system

Introduction to Concentrated Solar Thermal Technologies

Linear Fresnel Technology

Parabolic Through Technology

Central Receiver Technology

Dish/ Stirling Technology

Geometric Concentration / Operating temperatures

CSP commercial deployment status/ Context

January 2023 status (current operative plants):

NOMINAL POWER	Operation	Construction	TOTAL
Parabolic Trough	4.737 MW	643 MW	5.380 MW
Tower Systems	1.298 MW	410 MW	1.708 MW
Linear Fresnel	254 MW	104 MW	358 MW
TOTAL	6.289 MW	1.157 MW	7.446 MW

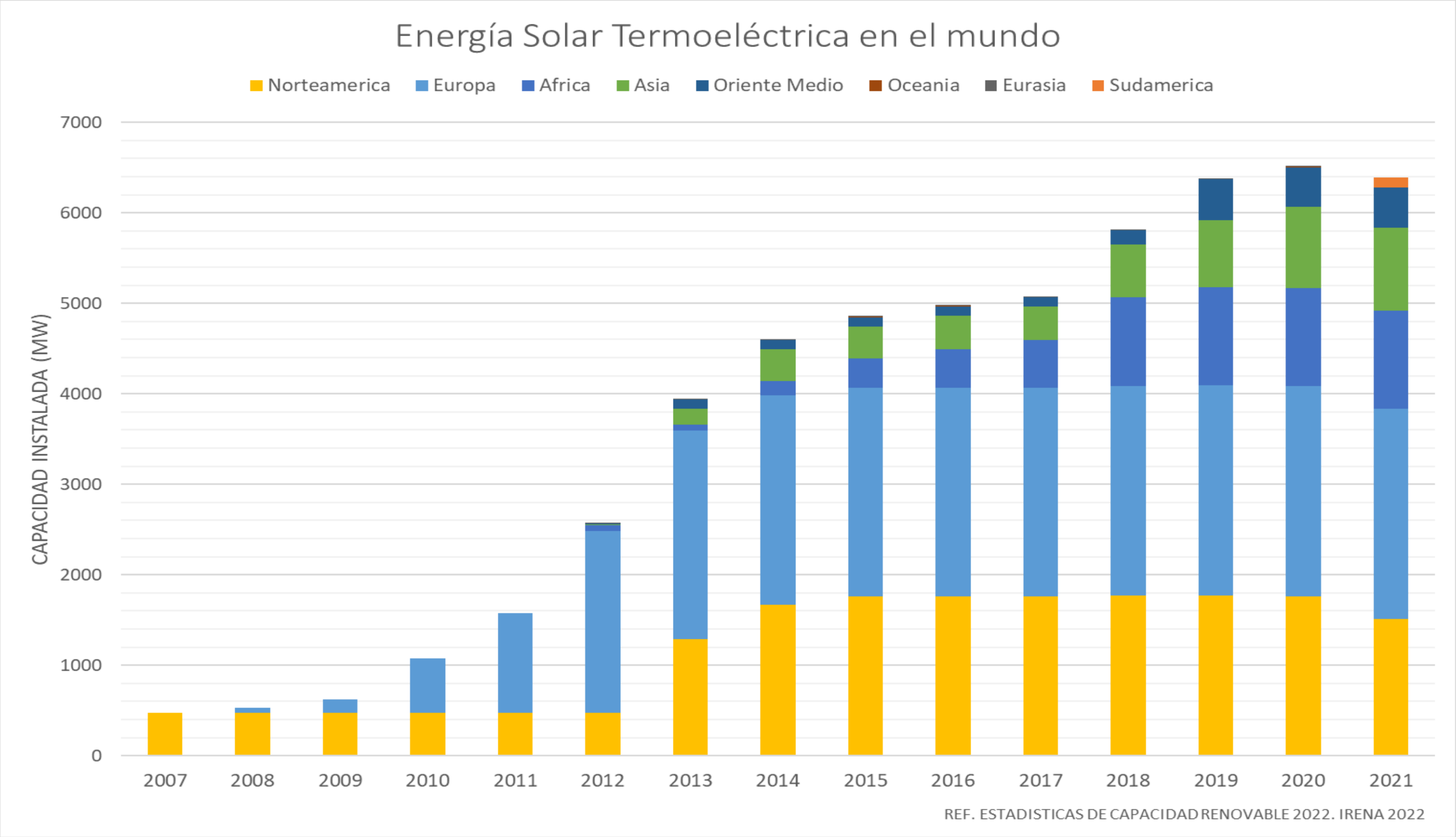
Number of Projects	110	8	118

Contribution of Spanish companies

77 % *64 %*

www.protermosolar.com
www.solarpaces.org

Context: When and where does standardisation work start in CSP or STE?



Spain . Country with the highest operating capacity worldwide

2007-2013
50 CSP Plants
were comissioned
2.3 GWe

Objetive: Establish a common framework for suppliers, manufacturers, researchers and buyers for the development and improvement of concentrating solar thermal technologies.

Standardisation committees

UNE Normalización Española

(Previously AENOR) **Spanish Standardisation Organisation**

2010

Creation of the standardisation subcommittee **“CentralesTermosolares”**

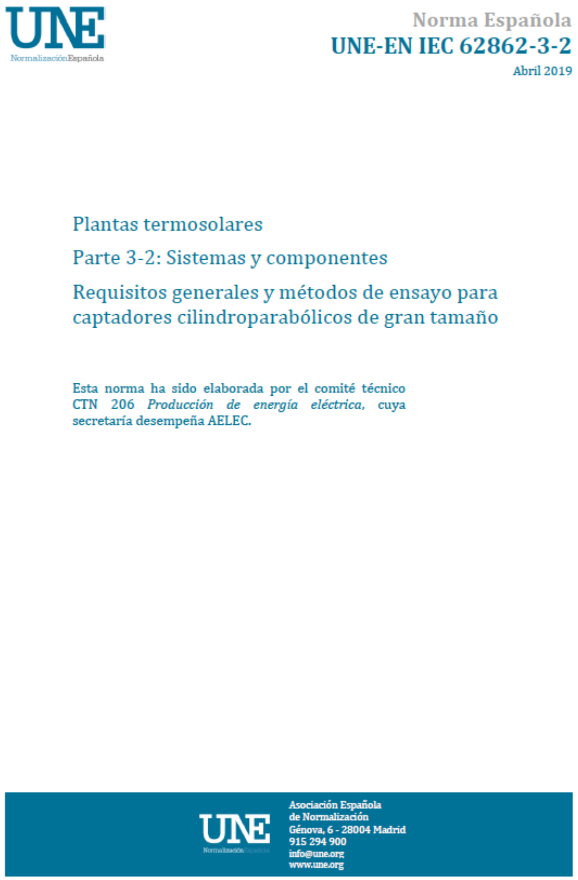
AEN/CTN 206/SC117

Technical Comittee 206:
PRODUCTION OF ELECTRICAL ENERGY

2021

Standardisation Committee **“CentralesTermosolares”**

CTN-UNE 224


UNE Normalización Española

Norma Española
UNE-EN IEC 62862-3-2
Abril 2019

Plantas termosolares

Parte 3-2: Sistemas y componentes

Requisitos generales y métodos de ensayo para captadores cilindroparabólicos de gran tamaño

Esta norma ha sido elaborada por el comité técnico CTN 206 *Producción de energía eléctrica*, cuya secretaría desempeña AELEC.

UNE Normalización Española
Asociación Española de Normalización
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www.une.org

Standardisation committees

SCOPE: Preparing Spanish standards 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.

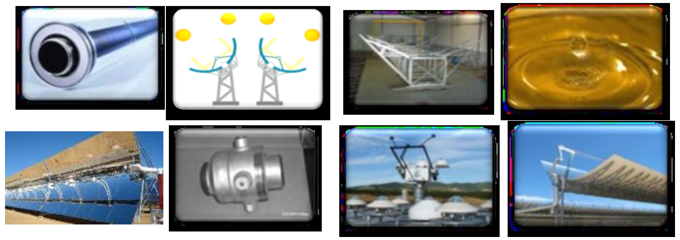
GT1

Complete Plant

Development of standards related to the **Standard Meteorological Year** and the commissioning and **qualification of solar fields** and complete plants, including general **terminology**.

GT2

Components



GT3

Thermal Storage Systems

Specific standards for the evaluation of **thermal storage** in parabolic trough plants, tower power plants and also for specific components

10 UNE STANDARDS PUBLISHED

Standardisation committees

UNE Normalización Española → IEC International Electrotechnical Commission

2012

Creation of international technical Committee **IEC 117 "Solar Thermal Electric Plants "**

TC 117 Scope

To prepare international standards 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.

The standards would cover all of the current different types of systems in the STE field, as follows:

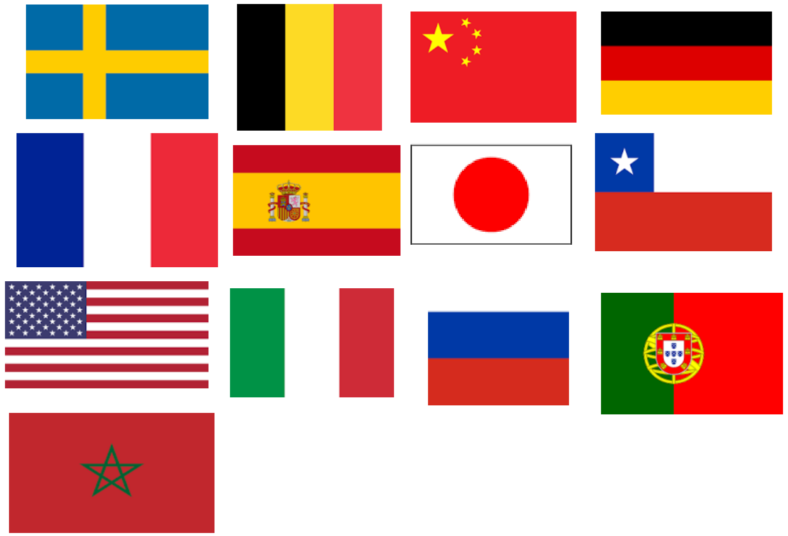
- Parabolic trough;
- Solar tower;
- Linear Fresnel;
- Dish;
- Thermal storage.

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

The standards would also address issues of connectivity and interoperability with the power grid related to connections, bi-directional communicates and centralized control (Smart Grid) and environmental aspects.

IEC- TC 117: membership

Country	Country Code	P/O Status	IEC Membership
United Arab Emirates	AE	O-Member	Full Member
Austria	AT	O-Member	Full Member
Belgium	BE	P-Member	Full Member
Switzerland	CH	O-Member	Full Member
Chile	CL	P-Member	Full Member
China	CN	P-Member	Full Member
Czech Republic	CZ	O-Member	Full Member
Germany	DE	P-Member	Full Member
Denmark	DK	O-Member	Full Member
Egypt	EG	O-Member	Full Member
Spain	ES	P-Member	Full Member
France	FR	P-Member	Full Member
United Kingdom	GB	O-Member	Full Member
Israel	IL	O-Member	Full Member
Iran	IR	O-Member	Full Member
Italy	IT	P-Member	Full Member
Japan	JP	P-Member	Full Member
Korea, Republic of	KR	O-Member	Full Member
Morocco	MA	P-Member	Associate Member
Mexico	MX	O-Member	Full Member
Poland	PL	O-Member	Full Member
Portugal	PT	P-Member	Full Member
Romania	RO	O-Member	Full Member
Russian Federation	RU	P-Member	Full Member
Sweden	SE	P-Member	Full Member
United States of America	US	P-Member	Full Member
South Africa	ZA	O-Member	Full Member



Secretariat: Spain
Participants countries: 13
Observer countries: 14

IEC Comittee: Projects

Project Reference	Title	Init. Date	Committee Date	Enquiry Date	Approval Date	Publication. Date
IEC 62862-1-4 ED1	Solar thermal electric plants - Part 1-4: Thermal insulation for solar thermal electric plants	2020-10	2023-06-30	2023-12-31		2025-06-30
IEC 62862-1-5 ED1	Solar thermal electric plants - Part 1-5: Performance code test for solar thermal electric plants	2021-06	2022-09-29	2023-06-22	2024-04-12	2024-01-08
IEC 62862-1-6 ED1	Solar thermal electric plants - Part 1-6: Silicone-based heat transfer fluids for use in line-focus concentrated solar power applications	2021-05	2022-01-20	2022-10-20	2023-09-08	2024-01-25
IEC 62862-2-2 ED1	Solar thermal electric plants - Part 2-2: Thermal energy storage systems - Technical requirements for molten salt used as heat storage and heat transfer medium.	2023-07	2024-05-16	2025-07-31		2026-05-14
IEC 62862-3-4 ED1	Solar thermal electric plants - Part 3-4: Code of solar field performance test for parabolic trough solar thermal power plant	2020-10	2023-06-30	2023-12-31		2025-06-30
IEC 62862-3-5 ED1	Solar thermal electric plants - Part 3-5: Laboratory reflectance measurement of solar reflectors	2021-05	2023-03-30			2025-03-31
IEC 62862-3-6 ED1	Solar thermal electric plants - Part 3-6: Durability of silvered-glass reflectors - Laboratory test methods and assessment	2021-05	2023-03-31			2025-03-31
IEC 62862-4-2 ED1	Solar thermal electric plants - Part 4-2: Heliostat field control system of solar tower plants	2022-01	2022-12-31	2023-11-30	2024-06-28	2024-12-31
IEC 62862-4-3 ED1	Solar thermal electric plants - Part 4-3: Technical requirements and design qualification of heliostats for solar power tower plants	2023-09	2024-07-31	2025-01-30	2025-07-04	2025-12-04

IEC- TC 117 Committee

Since its creation in 2012, the IECTC117 committee received numerous proposals for the creation of IEC standards from the Spanish committee.

Several proposals came from UNE standards already published in Spanish

Other came from working documents prepared by the working groups of the UNE committee, but not yet published.


IEC TS 62862-1-1

Edition 1.0 2018-02

TECHNICAL SPECIFICATION

Solar thermal electric plants –
Part 1-1: Terminology

Up to now, 9 IEC documents have been published (standards and technical specifications)

9 projects are actives (4 of them led by Spanish people)

Standardisation committees

Spanish Standards as a source of IEC standards.

UNE 206009:2013
Terminología. → IEC TS 62862-1-1:2018 ED1.0

UNE 206011:2014
Procedimiento de generación de Año Solar Representativo. → IEC TS 62862-1-2:2017 ED1.0

UNE 206013:2017
Procedimiento de generación de años percentiles de radiación solar. → IEC TS 62862-1-3:2017 ED1.0

UNE-EN IEC 62862-3-2:2019
Parte 3-2: Sistemas y componentes. Requisitos generales y métodos de ensayo para captadores cilindroparabólicos de gran tamaño. → IEC 62862-3-2:2018 ED1.0

UNE 206010:2015
Ensayos para la verificación de las prestaciones de las centrales termosolares con tecnología de captadores cilindroparabólicos. → IEC 62862-1-5:2023

- **IEC TS 62862-1-1:2018 ED1.0**
- **IEC TS 62862-1-2:2017 ED1.0**
- **IEC TS 62862-1-3:2017 ED1.0**
- IEC TS 62862-2-1:2021 ED1.0
- IEC 62862-3-1:2022 ED1.0
- **IEC 62862-3-2:2018 ED1.0**
- IEC TS 62862-3-3:2020 ED1.0
- IEC 62862-4-1:2022 ED1.0
- IEC 62862-5-2:2022 ED1.0
- **IEC 62862-1-5:2023**

Other codification activities

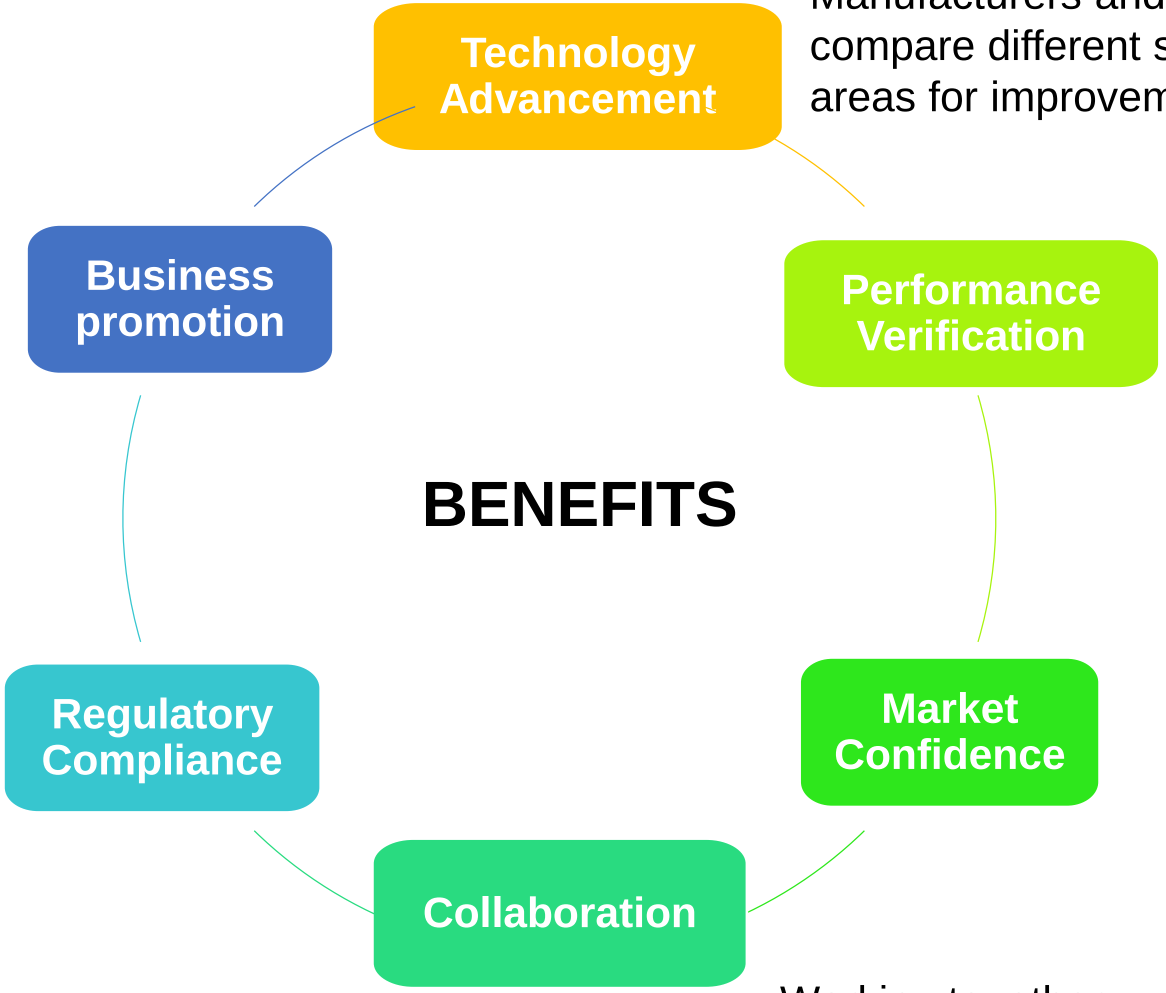
SolarPACES (Solar Power and Chemical Energy Systems)

SolarPACES is an **international cooperative network** of researchers and industry experts bringing together teams of national experts from around the world to **focus on the development and marketing** of CSP systems. It is one of the collaborative programs, called Implementing Agreements, managed under the umbrella of the **International Energy Agency** to help find solutions to worldwide energy problems

Mission: To facilitate technology development, market deployment and energy partnerships for sustainable, reliable, efficient and cost-competitive concentrating solar technologies.

- ✓ Organizing international conferences
- ✓ Providing opportunities for joint projects in order to encourage energy partnerships between countries
- ✓ **Developing guidelines** and **support standards** in order to increase the transparency of the market and reduce risks associated with project development.

The importance of standardisation



Manufacturers and researchers can compare different systems and identify areas for improvement

Assure that systems deliver the expected output

For investors and end-users, standardized testing offers assurance

Working together, sharing knowledge

Supporting legislation and public policies, making easier the approval process for projects.

Making easier for companies to access markets, reducing technical barriers and offering quality and safety guarantees

Examples

SolarPACES Task III : Developing methods and procedures for predicting the life-time performance of solar plant components and systems, . Including the development of methods for long-term stability testing (e.g., accelerated aging procedures).

SolarPACES STAGE STE EERA Federal Ministry for Economic Affairs and Energy EERA

Guidelines

ACCELERATED AGING TESTING OF ALUMINUM REFLECTORS FOR CONCENTRATED SOLAR POWER

Version 1.1

August 2016

Authors: F. Sutter (DLR), J. Wette (DLR), A. Fernández-García (CIEMAT), S. Ziegler (Alanod), R. Dasbach (Almeco)

With contributions from Radia Lahlou (MASDAR)

Table 2: Accelerated aging testing sequence

	Accelerated aging step		1	2	3	4
Method	Simulated reference site	Simulated Years	ISO9227: CASS Test [testing time in h]	DIN 52348: Sand trickling [sand mass in g]	ISO9227: CASS Test [testing time in h]	ISO 16474-3, Method A, cycle No. 1 [testing time in h]
A1	Extreme Desert	3	-	180	2	480
A2		10	-	600	8	480
B1	Desert	3	-	5	8	480
B2		10	-	15	24	480
C1	Coastal	3	96	5	8	480
C2		10	312	15	24	480

Ciemat PSA

Examples

SolarPACES
Solar Power & Chemical Energy Systems

...idelines

...THE REFLECTANCE
...ONCENTRATING
...CONDITIONS

Transferred to IEC Project Team (2021) (IEC TC 117 / PT 62862-3-5) LABORATORY REFLECTANCE MEASUREMENT OF CONCENTRATING SOLAR THERMAL REFLECTORS”.

Official Reflectance Guideline Version 3.1

April 2020

Authors of current version (3.0): Aránzazu Fernández-García (CIEMAT), Florian Sutter (DLR), Marco Montecchi (ENEA), Fabienne Sallaberry (CENER), Anna Heimsath (Fraunhofer ISE), Carlos Heras (Universidad de Zaragoza), Estelle Le Baron (CEA), Audrey Soum-Glaude (PROMES-CNRS)

SolarPACES
Solar Power & Chemical Energy Systems

Guidelines

...ECTANCE, ABSORPTANCE AND
...ONCENTRATING SOLAR

SOLARPACES Project funding: “Characterization of optical properties of particles for CSP” DLR, CIEMAT, ENEA, Universitat Barcelona, NREL and SANDIA.

Version 1

May 2022

Authors: F. Sutter, J. Pernpeintner, S. Caron (DLR), A. Morales, G. San Vicente, A. Fernández-García (CIEMAT), M. Montecchi (ENEA), A. Calderón, M. Majó, I. Fernández (Universitat Barcelona), P. Davenport, T. Farrell (NREL) and C. Ho (SANDIA)

Examples

Guidelines

Silicone-Based Heat Transfer Fluids (SiHTF) in Line Focusing Concentrating Solar Power Applications

Version 1.0

February 2021

Authors: C. Hilgert (DLR), C. Jung (DLR), L. Valenzuela (CIEMAT), E. Schaffer (WACKER), D. Lei (IEECAS)

With contributions from: K. Schickedanz (WACKER) S. Martínez (TSK FLAGSOL), M. Schmitz (TSK FLAGSOL), P. Guth (DMT), C. Wasserfuhr (TÜV Nord), H. Bouzekri (MASEN)

It covers general information for selecting standard and non-standard test methods for evaluating silicone-based heat transfer fluids in line focusing concentrating solar power applications.

Transferred to IEC Project Team (May 2021) (IEC 62862-1-6 ED1) Solar thermal electric plants - Part 1-6: Silicone-based heat transfer fluids for use in line-focus concentrated solar power applications

Examples

2 Thermal stability

2.1 Fluid thermal stability

According to UNE 206015 the fluid thermal stability is the resistance of a heat transfer fluid against cracking within a temperature range for which it is specified.

According to GB 23971 the thermal stability is the ability of heat transfer fluids to resist chemical decomposition under high temperature condition.

Note: with increase of temperature, heat transfer fluids will go through chemical reaction or molecular rearrangement, and the resulting gaseous decomposition products, low-boiling components, high-boiling components and nonvolatile decomposition products will influence the performance of heat transfer fluids.

2.1.1 Relevance to CSP applications

The thermal stability of an HTF typically limits and thus determines the maximum operating temperature (see section 2.7 Maximum permitted bulk temperature) of parabolic trough power plants. This value is also used to estimate the life span and exchange rate (if needed) of the HTF under operating conditions.

2.1.2 Summary of standards

- UNE 2016015 — DIN 51528:1998-07, Testing of mineral oils and related products - Determination of thermostability of unused heat transfer fluids
- DIN 51522 — DIN 51528:1998-07
- DIN 51529 — DIN 51528:1998-07
- GB 23971 — GB/T23800, Heat transfer fluids – Determination of thermal stability
- ASTM D5372 — ASTM D6743 - 11(2015), Standard Test Method for Thermal Stability of Organic Heat Transfer Fluids
- ASTM D7665 — ASTM D6743 - 11(2015)

2.1.3 Description of methods

DIN 51528, GB/T23800: To assess the thermal stability of the HTF mass fractions of high and low boilers together with gases and nonvolatile decomposition products of the heat-stressed fluid are used to detect the entire degree of decomposition of the heat carrier. The mass fraction of gaseous reaction products is generally negligible. The heat transfer medium to be tested is melted into a borosilicate glass ampoule or filled into a stainless-steel test vessel and sealed gas-tight. For safety reasons, the glass ampoules are inserted in a metallic protective tube. The glass ampoules in the protective tube or the test vessel are tempered for a specified period of time at a test temperature of ± 1 K. The test temperature is advantageous to be set in the upper application temperature of the individual heat carrier. For each test an unused heat transfer medium has to be used. After completion of the annealing and opening of the glass ampoules or test vessels, the mass fraction is evaluated. Low and high boilers of the test substance determined by gas chromatography based on DIN 51435. All non-evaporable products which cannot be detected by gas chromatography shall be determined separately in a ball tube distillation apparatus (at 250 °C and 0.1 mbar). The test results of

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50 °F). The
est method,
ng the test.

2.1.4 Differences of methods

GB/T 23800, DIN 51528 and ASTM D6743 are equivalent. According to GB/T 23800 the capacity of the glass ampoules is 15 ml, the testing time is 720 h and the determination of low and high boilers of the test substance by gas chromatography (DIN 51435) is required. DIN 51528 defines the glass ampoules to be at least 5 ml, a testing time of at least 480 h and requires gas chromatographical analysis of low and high boilers (DIN 51435) as well as determination of gases via weight loss between closed and opened ampoules and nonvolatile products via ball-tube distillation up to 250 °C and 0.1 mbar. ASTM D6743 requires at least 27 g HTF and a test period of at least 500 h. GB/T added the requirement of weighting accuracy and the report of the change in appearance after and before testing.

2.1.5 Applicability of methods

DIN 51528 and ASTM D6743 presuppose that all formed low and high boilers (higher and lower as the HTF) are degradation products. In both standards it is stated that they have not been evaluated for silicone fluids. SiHTF equilibrates and forms high and low boilers during operation. The formed low and high boilers are still part of SiHTF and therefore cannot be considered as degradation products. In other words, equilibrated SiHTF consists of high and low boiling components.

2.1.6 Alternatives / more suitable methods

Silicone-based heat transfer fluids (SiHTF) in general are polymeric mixtures of linear siloxanes. Concerning the thermal stability of SiHTF, the determination of the T-unit amount can be applied:

Unused SiHTF contain low values of T-units (in the lower ppm range < 1000 ppm). During operation above 250 °C, T-units are continuously formed and will slowly lead to branching of the former separate siloxane molecules. The amount of T-units present in the SiHTF is therefore linked with the viscosity of the fluid. In the end, higher amounts of T-units could lead to a viscosity increase.

The amount of T-units can be determined via NMR-spectroscopy - the maximum tolerable amount of T-units depend on the fluid composition and has to be defined by the fluid manufacturer.

Examples

IEC TS 62862-3-3

Edition 1.0 2020-02

TECHNICAL SPECIFICATION

colour inside

Solar thermal electric plants –
Part 3-3: Systems and components – General requirements and test methods for solar receivers

Durability tests of receiver materials (parabolic through)

- Stationary abrasion resistance test of antireflective coatings
- Condensation resistance test
- Thermal stability of selective absorbers coatings for stainless Steel samples
- Thermal cycling test
- Mechanical fatigue of bellows
- Impact with ice balls

Conclusions/outlook

Standardisation activities in CST emerged with the commercial take-off of the technology, accompanying it. There is still much to be done.

It is a complex task considering the variety of technologies and the different operating conditions of each of them (operating temperatures, materials, pressures, climatic conditions.. etc.).

Spain plays an important role in the development of these technologies and therefore also in the standardisation activities. A great effort has been made among manufacturers, researchers, purchasers and end-users to reach consensus.

Thank you very much for your attention

Questions?

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