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Summary of Standardization for Concentrating Solar Plants in Industrial Processes

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Abstract. The Solar Heat Integration in Industrial Processes (SHIP) covers a wide range of temperature applications, from low temperature for which need flat plate collectors (FPC) or evacuated tubes collectors (ETC), to high temperature which need larger parabolic-trough collectors (PTC), linear Fresnel (LFR) or solar tower (ST), like the one installed in Concentrating Solar Power (CSP) plants. This paper aims to present a summary of all the existing standards (published or in work process) that should be used in a SHIP plant to regulate and ensure the products used in those renewable energy thermal plants.

Keywords: Standardization, SHIP

1. Introduction

The transition to sources of renewable energy is now more than ever of enormous importance, not only for the fight against climate change, but also for the safety of the energy supply. Today, unfortunate geopolitical events in Europe, like the war in Ukraine, have highlighted Europe's energy dependence on foreign fossil fuels. Solar thermal energy for electricity or industrial heat production is part of the solution, supplying thermal energy through solar thermal power plants.

Spain is today the world leader in both installed solar thermal power and technological capacity, and it was the country where the world's first commercial central tower solar thermal plant was installed, PS10 in Seville (Spain). More recently, at the end of 2023, the largest industrial concentrating solar thermal plant of 30 MW was inaugurated for the Heineken brewery plant near Seville. Currently, Spain has 49 CSP plants in operation for electricity production that total 2,300 MW of power [1], and 47 SHIP plants with concentrating collectors that total 37.78 MWt of power [2], being the market with the greatest operational capacity in the world.

For the solar thermal energy sector, the standardization activity constitutes a strategic aspect due to the need to harmonize the design criteria of the components and subsystems that make up the technology, to increase the confidence of investors and insurers and, thus, ensuring greater bankability of the projects, and continue strengthening the international projection of the sector [3]. In that direction, the standards available should be considered by the market, the stakeholders and, in last term, by policy makers.

2. Definition and background

A standard is a technical document designed for voluntary use which results from consensus, based on the results of experience and technological development and approved by a recognized standardization body (IEC/ISO at the international level, CEN/CENELEC at the European level, etc.).

Standards guarantee levels of quality and safety that allow any company to better position itself on the market and constitute a significant source of information for professionals of any economic activity

A standard is not a law or regulation of the public administration, neither is a company or association specification sectorial or a “tailor-made” publication.

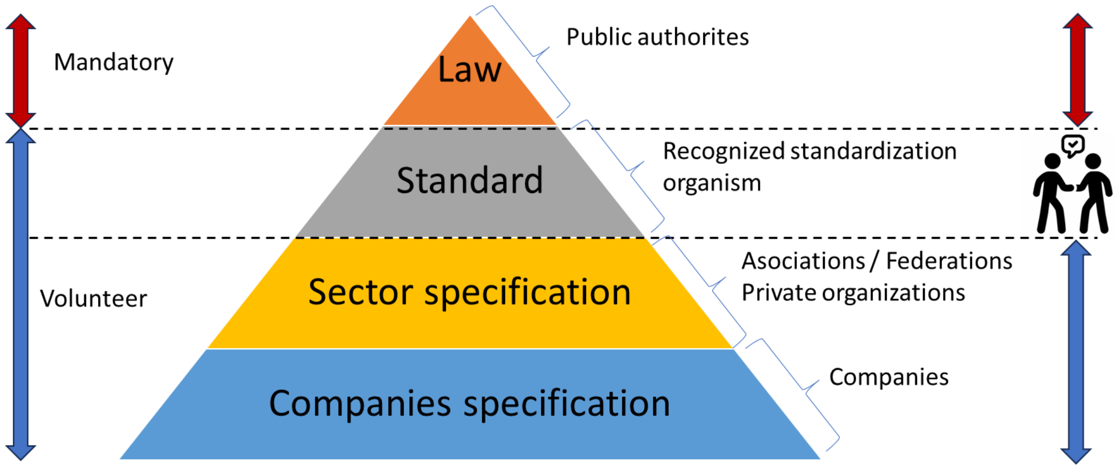

Figure 1. *Standard application (source UNE)*

The standardization presents the following advantages:

- Supports legislation and public policies (Facilitating policies, simplifying legal texts),
- Market surveillance (Provides credibility in markets, boosts activity industrial and constitutes a guarantee for the consumers),
- Helps the innovation (Facilitates the dissemination, knowledge transfer and the penetration on the market of innovations),
- Trade promotion (Provides companies with access to markets, reducing technical barriers and offers quality and safety guarantees),
- Improvements of the competitiveness business.

The standardization is a part of the whole quality chain, as seen in Fig. 2, within the certification bodies, the accreditation bodies, the metrology bodies, and the testing laboratories.

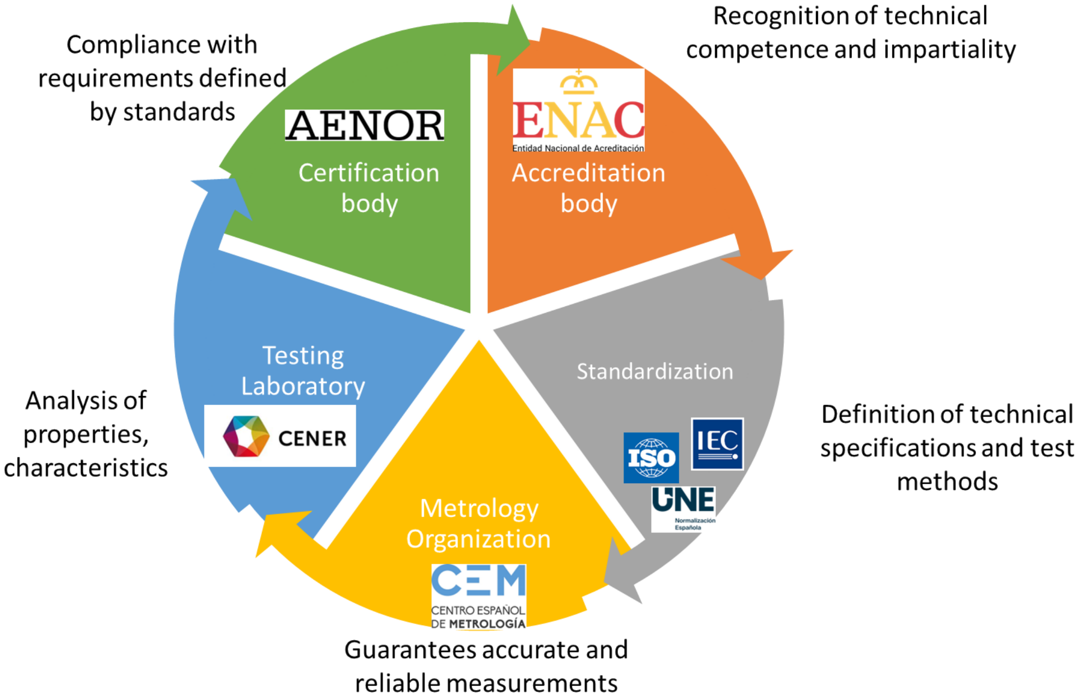

Figure 2. *Quality infrastructure for example with Spanish actors (source UNE)*

On the other hand, the certification of a product is a useful tool to add credibility, by demonstrating that a product or service meets the expectations of the customers [4]. In the Solar Thermal Energy applications different certification schemes exist worldwide (SolarKeymark in Europe, SRCC in USA, SHAMCI in Middle East and North Africa (MENA) or GSCN Worldwide). The certification process involves not only testing but also other quality requirements involving the intervention of a 3rd party. For instance, SolarKeymark Certification 4 pillars are random sampling of the products for type testing, initial type testing according to the applicable European standard, periodic surveillance of the manufacturers quality management system, periodic surveillance of the certified products. For now, for low-temperature products the certification schemes such as SolarKeymark in Europe, are well-known and even mandatory in many countries, but only a few concentrating tracking solar collectors are certified and only small aperture models [5-7].

3. Standardization Development

3.1 ISO TC 180 & CEN TC 312 committee

For the Solar Thermal Industry for low-temperature applications (i.e. domestic hot water) the International and European Standardization committees have been active for more than two decades. Experts from testing laboratories, universities, research centers, engineering companies and other in the sector participate in the standardization committees. For example, the international committee ISO TC 180 [8] for “Solar Energy” is dedicated to standardization in the field of solar energy utilization in space and water heating, cooling, air conditioning and industrial process heating. Table 1 gives a summary of ISO TC 180 standards.

Table 1. *ISO TC 180 standards of interest*

Standard (publication year)	Title / scope
ISO 9488 (2022)	Solar energy - Vocabulary
ISO 9806 (2017) (under revision)	Solar thermal collectors - Test methods
ISO 9808 (1990)	Elastomeric materials for absorbers, connecting pipes and fittings
ISO/TR 10217 (1989)	Water heating systems - Guide to material selection with regard to internal corrosion
ISO 22975-1 (2016)	Collector components and materials - Evacuated tubes — Durability and performance
ISO 22975-2 (2016)	Collector components and materials - Heat-pipes for solar thermal application — Durability and performance
ISO 22975-3 (2014)	Collector components and materials - Absorber surface durability
ISO 22975-5 (2019)	Collector components and materials - Insulation material durability and performance

The more relevant standard for SHIP developed by ISO TC 180 is ISO 9806 which gives the testing procedure for durability and characterization tests for all kind of solar thermal collectors, including concentrating tracking solar collectors. The collector's efficiency model is given by Eq. 1, simplified for concentrating solar collectors neglecting some parameters for the diffuse radiation, wind speed and IR radiation effects. The input variables are the direct solar irradiance G_{bn}, the fluid and ambient temperatures ϑ_m and ϑ_a, the thermal power $\dot{Q}$ and the collector area A_G.

$$\frac{\dot{Q}}{A_G} = \eta_{0,b} K_b(\theta_i) G_{bn} cos\theta_i - a_1(\vartheta_m - \vartheta_a) - a_2(\vartheta_m - \vartheta_a)^2 - a_5 \frac{d\vartheta_m}{dt} \quad (1)$$

In Eq. 1, the first term is optical efficiency $\eta_{0,b}$ and the K_b factor is the incidence angle modifier (IAM) to direct irradiance. The coefficients a_1 and a_2 are the heat losses. Depending on the concentrating ratio, the heat losses parameters could be change to a quadratic polynomial model with another coefficient a_8. The coefficient a_5 is the effective thermal capacity which depends on the derivate in time of the mean fluid temperature $\frac{d\vartheta_m}{dt}$.

The European committee CEN TC 312 [9] for "Thermal solar systems and components" is dedicated to standardization of terminology, general requirements, characteristics, test methods, conformity evaluation and labelling of thermal solar systems and components. Table 2 gives a summary of CEN TC 312 standards.

Table 2. *CEN TC 312 standards of interest*

Standard (publication year)	Title / scope
EN ISO 24194 (2022) (under revision)	Collector fields - Check of performance
EN 12975 (2022)	Solar collectors - General requirements
EN 12976-1 (2021)	Factory made systems - General requirements
EN 12976-2 (2019)	Factory made systems - Test methods
EN 12977-1 (2018)	Custom built systems - General requirements for solar water heaters and combisystems
EN 12977-2 (2018)	Custom built systems - Test methods for solar water heaters and combisystems
EN 12977-3 (2018)	Custom built systems - Performance test methods for solar water heater stores
EN 12977-4 (2018)	Custom built systems - Performance test methods for solar combistores
EN 12977-5 (2018)	Thermal solar systems and components - Performance test methods for control equipment

The more relevant standard for SHIP developed by CEN TC 312 is EN ISO 24194 which gives the testing procedure for checking the performance of a solar field, including concentrating tracking solar collectors. This procedure should be used as acceptance of the solar field, which consists in comparing the average measured power with the average power corresponding to the calculation of the estimated power from Eq.1. Three safety factors are also added to estimated power (f_P considering heat losses from pipes in the collector loop, f_U the safety factor from measurement uncertainty and f_0 the safety factor from for other uncertainties related to non-ideal conditions).

For longterm prediction of a SHIP plant there is no standard for now. But the procedure to estimate the performance of water custom built systems in domestic heating applications in standard EN 12977-2 could be used for a future standard.

3.2 CTN-UNE224 Spanish committee

The Spanish standardization committee CTN 224 “Solar thermal power plants” exists since 2010 and has published in a decade more than ten UNE national standards [10]. CTN 224 contributes to the sector by providing UNE standards in Spain, by promoting the creation of the IEC TC 117 in 2010, by sending several proposals of standards to this international committee, and as well as leading those working groups for publishing new standards. Table 3 gives a summary of the CTN 224 standards.

Table 3. *CTN 224 standards of interest*

Standard (publication year)	Title / scope (equivalence to IEC)
UNE 206011 (2014)	Representative Solar Year generation procedure. (~IEC TS 62862-1-2:2017)
UNE 206009 (2013)	Terminology. (~IEC TS 62862-1-1:2018)
UNE 206013 (2017)	Procedure for generating percentile years of solar radiation (~IEC TS 62862-1-3:2017)
UNE 206017 (2020)	Specific sensors for the global evaluation of solar thermal power plants.
UNE 206016 (2018)	Reflective panels for solar concentration technologies (~IEC 62862-3-5 & IEC 62862-3-6 on going)
UNE 206015 (2018)	Heat transfer fluids for solar thermal power plants with parabolic trough collector technology. Requirements and tests. (~IEC 62862-1-6 on going)
UNE 206010 (2015)	Tests to verify the performance of solar thermal power plants with parabolic trough technology. (~IEC 62862-1-5 on going)
UNE 206014 (2017)	Tests to determine the performance of the solar field of solar thermal power plants with parabolic trough technology.
UNE 206012 (2017)	Characterization of the thermal storage system for solar concentration applications with parabolic trough collectors (~IEC TS 62862-2-1:2021)
UNE 224001 (2023)	Criteria for design, installation and verification of the performance of kinematic joints in solar thermal power plants with parabolic trough technology (~IEC 62862-3-7 on going)

3.3 IEC TC 117 committee

The international committee IEC TC 117 [11] is dedicated to 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). The standards published by this committee cover all the current different types of systems in the STE field, as: parabolic trough (PTC), solar tower, linear Fresnel (LFR), parabolic dish, thermal storage. Since its inception, the Spanish solar thermal industry has maintained an important participation in national and international technical standardization committees, essential to maintain its position in the market. Tables 4 and 5 gives a summary of IEC TC 117 standards.

Table 4. *IEC TC 117 standards of interest*

Standard (publication year)	Title / scope
IEC TS 62862-1-1 (2018)	Terminology
IEC TS 62862-1-2 (2017)	Creation of annual solar radiation data set for solar thermal electric (STE) plant simulation
IEC TS 62862-1-3 (2017)	Data format for meteorological data sets
IEC TS 62862-2-1 (2021)	Thermal energy storage systems - Characterization of active, sensible systems for direct and indirect configurations
IEC 62862-3-1 (2022)	General requirements for the design of parabolic-trough solar thermal power plants
IEC 62862-3-2 (2018)	General requirements and test methods for large-size parabolic-trough collectors
IEC TS 62862-3-3 (2020)	General requirements and test methods for solar receivers
IEC 62862-4-1 (2022)	General requirements for the design of solar power tower plants
IEC 62862-5-2 (2022)	General requirements and test methods for large-size linear Fresnel collectors
IEC 62862-1-5 (2024)	Performance test code for solar thermal electric plants
IEC 62862-1-6 (2024)	Silicone-based heat transfer fluids for use in line-focus concentrated solar power applications

Table 5. *IEC TC 117 Working projects (in redaction)*

Standard (estimation year of publication)	Title / scope
IEC 62862-1-4 (2025)	Thermal insulation for solar thermal electric plants
IEC 62862-2-2 (2026)	Thermal energy storage systems - Technical requirements for molten salt used as heat storage and heat transfer medium
IEC 62862-3-4 (2025)	Code of solar field performance test for parabolic trough solar thermal power plant
IEC 62862-3-5 (2025)	Laboratory reflectance measurement of solar reflectors
IEC 62862-3-6 (2025)	Durability of silvered-glass reflectors - Laboratory test methods and assessment
IEC 62862-3-7 (2026)	Criteria for design, installation and performance verification of flexible pipe connectors in parabolic trough collector technology
IEC 62862-4-2 (2025)	Heliostat field control system of solar tower plants
IEC 62862-4-3 (2025)	Technical requirements and design qualification of heliostats for solar power tower plants

The more relevant standards for SHIP developed by IEC TC 117 are IEC 62862-3-2 and IEC 62862-5-2 which give the testing procedure for characterization tests for PTC and LFR collectors respectively, referring to ISO 9806. The technical specification IEC TS 62862-3-3 gives the testing procedure for durability and characterization tests of receiver tubes.

3.4 American ASTM and ASME committees

In the USA, the ASTM [12] and ASME [13] associations published numerous standards or technical specifications. Table 6 gives a summary of ASTM and ASME standards.

Table 3. *ASTM and ASME standards of interest*

Standard (publication year)	Title / scope
ASTM E905 (2021)	Standard Test Method for Determining Thermal Performance of Tracking Concentrating Solar Collectors
ASTM E744-07 (2022)	Standard Practice for Evaluating Solar Absorptive Materials for Thermal Applications
ASTM E861-13 (2021)	Standard Practice for Evaluating Thermal Insulation Materials for Use in Solar Collectors
ASTM D3771-15 (2022)	Standard Specification for Rubber Seals Used in Concentrating Solar Collectors
ASTM D3667-16 (2022)	Standard Specification for Rubber Seals Used in Flat-Plate Solar Collectors
ASTM STP36063S NBS	Solar Collector Durability/Reliability Program
ASME PTC 52 (2021)	Concentrating Solar Power Plants

3.5 Non-standardization experts groups

Other groups of experts are also dealing with standardization of the testing procedure for concentrating solar thermal technology or SHIP. Those groups do not publish standards as they are not official standardization organisms but can redact relevant guidelines that could be used as the basis for standards.

The SolarPACES association (Solar Power and Chemical Energy Systems) is one of several Technology Collaboration Programmes (TCP) organized within the framework of the International Energy Agency (IEA). It contains a specific Task III for “Solar Technology and Advanced Applications” and another Task IV for “Solar Heat Integration in Industrial Processes” [14-15].

The IEA-SHC (Solar Heating and Cooling Technology Collaboration Programme) is one of the first programmes of the International Energy Agency (IEA). Different tasks are dealing with SHIP for instance, Task 49 “Solar Heat Integration in Industrial Processes” [16], Task 64 “Solar Process Heat” [17] and Task 68 “Efficient Solar District Heating Systems” for large solar field [18].

4. Roadmap and Conclusions

This paper presents a summary of the standardization committees and experts groups dealing with solar thermal energy and more specifically with technologies applicable in SHIP plants as concentrating solar technology.

Regarding SHIP plants acceptance purposes, the main applicable standards in force are:

- ISO 9806 for testing procedure for durability and optical and thermal characterization tests for the solar thermal collectors.
- EN ISO 24194 for the procedure for the verification of solar field performance.

Taking advantage of the experience gained in developing component testing standards for solar thermal power generation applications, there are several standards developed that can also be applied to accept components, collectors or entire SHIP plants.

For future works, the long-term prediction of SHIP is not standardized yet. Different simulation tools exist and are already used by Industry. But there is still no consensus for a guideline for the simulation calculation like standard EN 12977 series, which uses the customer's load curve and the typical meteorological data (TMY).

Author contributions

Fabienne Sallaberry: Conceptualization, Methodology, Writing – original draft. **Alberto García de Jalón**: Supervision. **Egoitz San Miguel**: Supervision. **Ana María Mariblanca:** Supervision. **Sandra Cubero:** Supervision. **Loreto Valenzuela:** Supervision.

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Competing interests

The authors declare that they have no competing interests.

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