International Workshop on "*Materials resistant to extreme conditions for future energy systems*"

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Technical Requirments for Concentrating Solar Thermal Systems Materials

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Concentrating Solar Thermal Systems

INDEX OF THE PRESENTATION

- **Brief introduction to the CST Systems**
- **Advanced materials for CST Systems**
- **CST facilities for extreme conditions testing**
- **Final remarks**

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Concentrating Solar Thermal Systems

What is a Concentrating Solar Thermal (CST) System ?

A CST system collects and concentrates the direct solar radiation to convert it into thermal energy at medium/high temperature (even higher than 2000ºC). This thermal energy is then used to either feed an industrial thermal process or produce electricity.

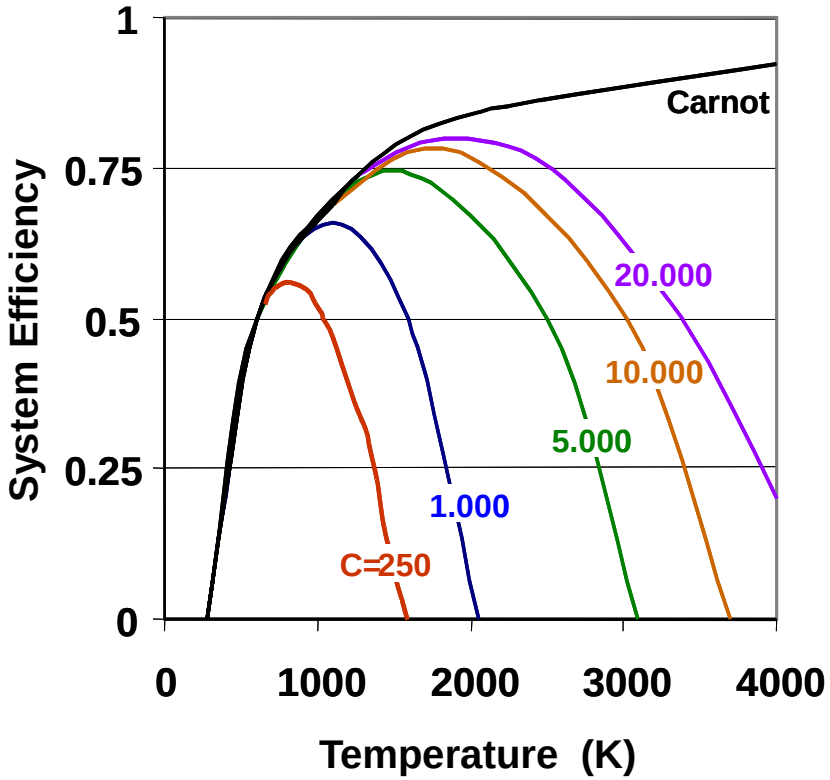
Why concentration ?

Concentration is required to compensate for the great attenuation suffered by the solar radiation in its way from the Sun (63 MW/m^2) to the Earth (1 kW/m^2).

Concentrating Solar Thermal Systems

Efficiency versus Concentration Factor

$\eta = f(C, T)$



Dependence of the *Efficiency* and the *Optimum Working Temperature* on the *Solar Radiation Concentration Factor*

Concentrating Solar Thermal Systems

What is a Concentrating Solar Thermal (CST) System ?

A CST system collects and concentrates the direct solar radiation to convert it into thermal energy at medium/high temperature (even higher than 1000ºC). This thermal energy is then used to either feed an industrial thermal process or produce electricity.

Why concentration ?

Concentration is required to compensate for the great attenuation suffered by the solar radiation in its way from the Sun (63 MW/m^2) to the Earth (kW/m^2).

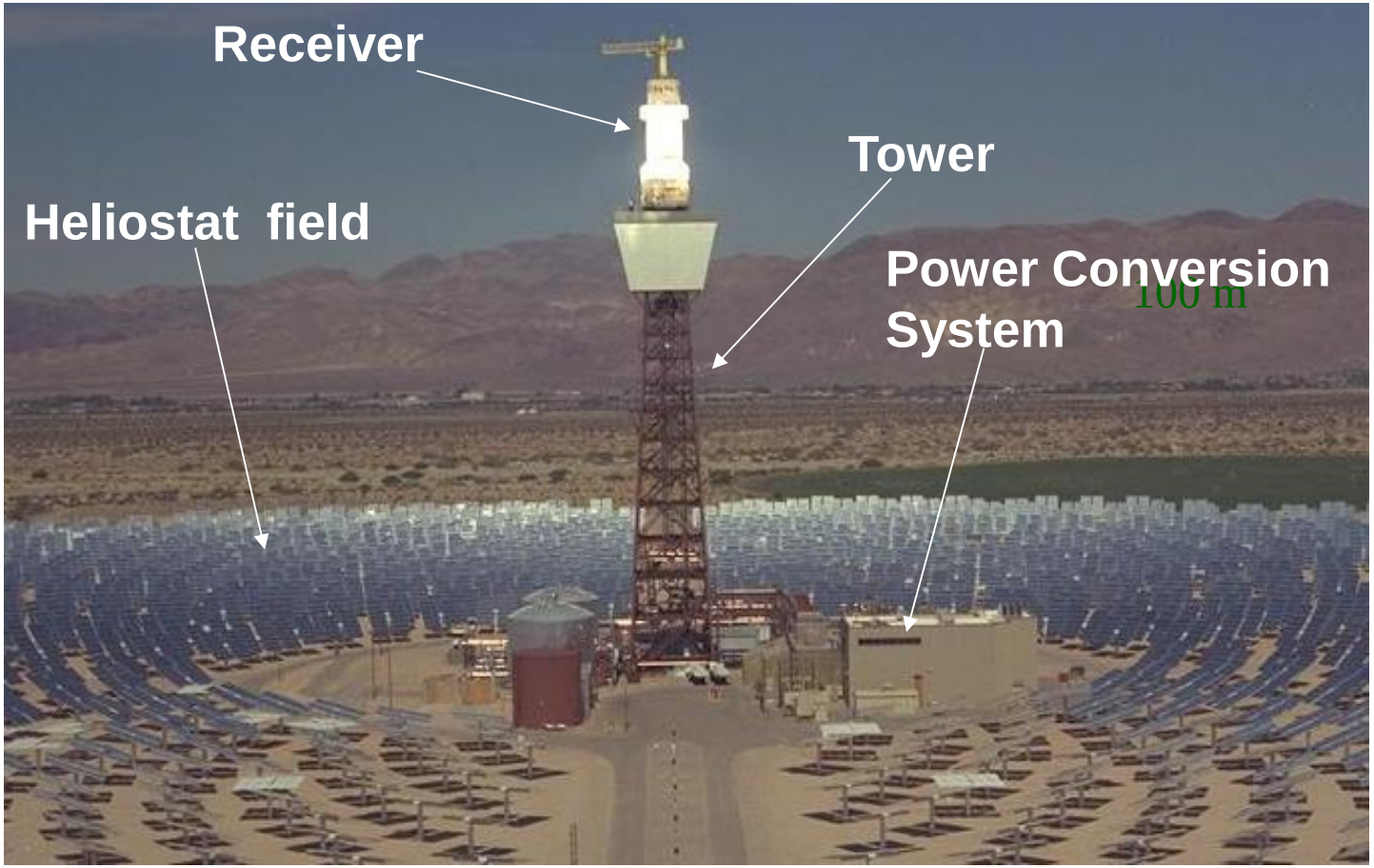
CST technologies:

There are four different CST technologies:

- ✓ Central receiver plants
- ✓ Parabolic trough collectors
- ✓ Stirling dishes
- ✓ Linear Fresnel concentrators

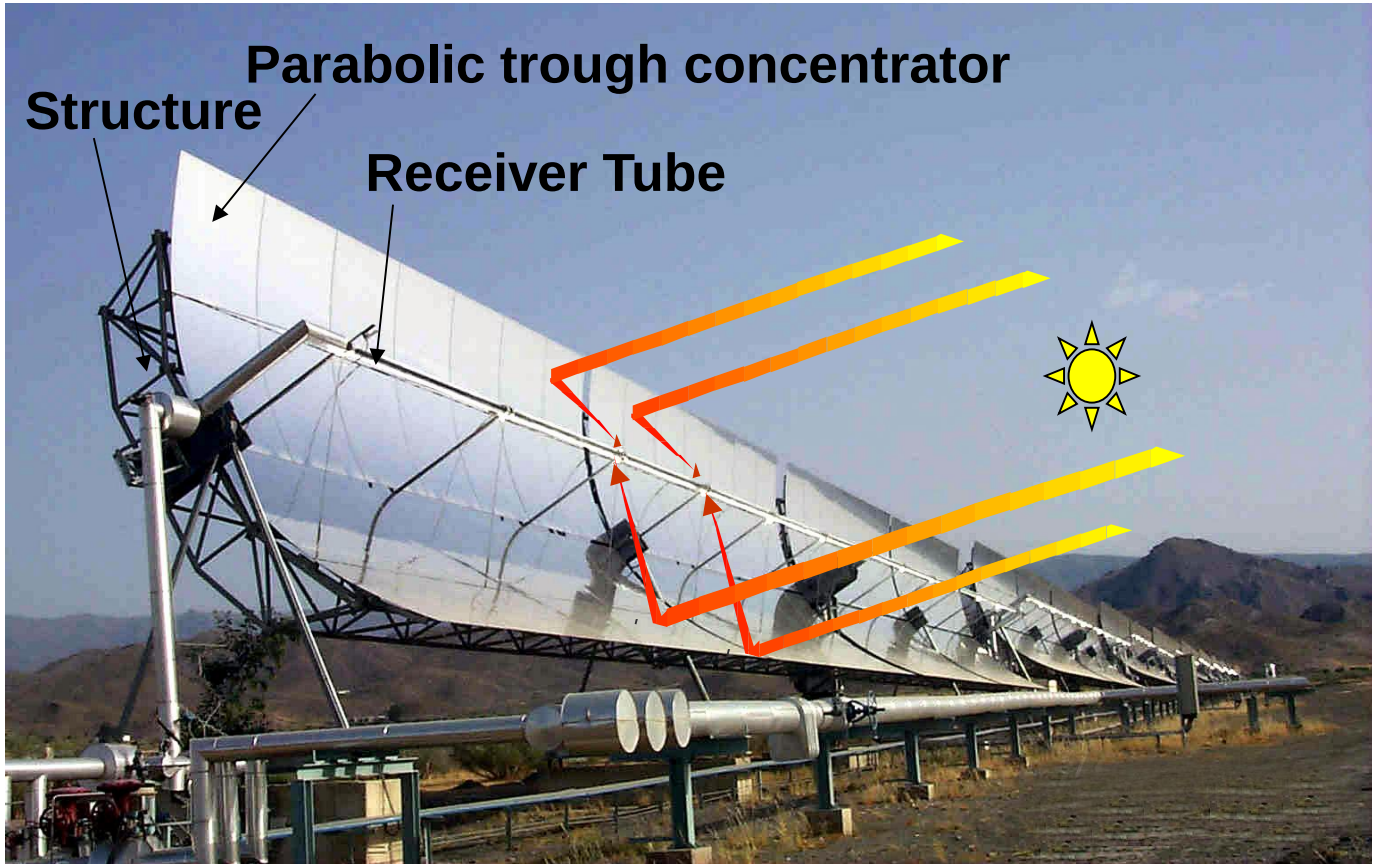
CST Technologies

Central Receiver Technology



CST Technologies

Parabolic Trough Collectors

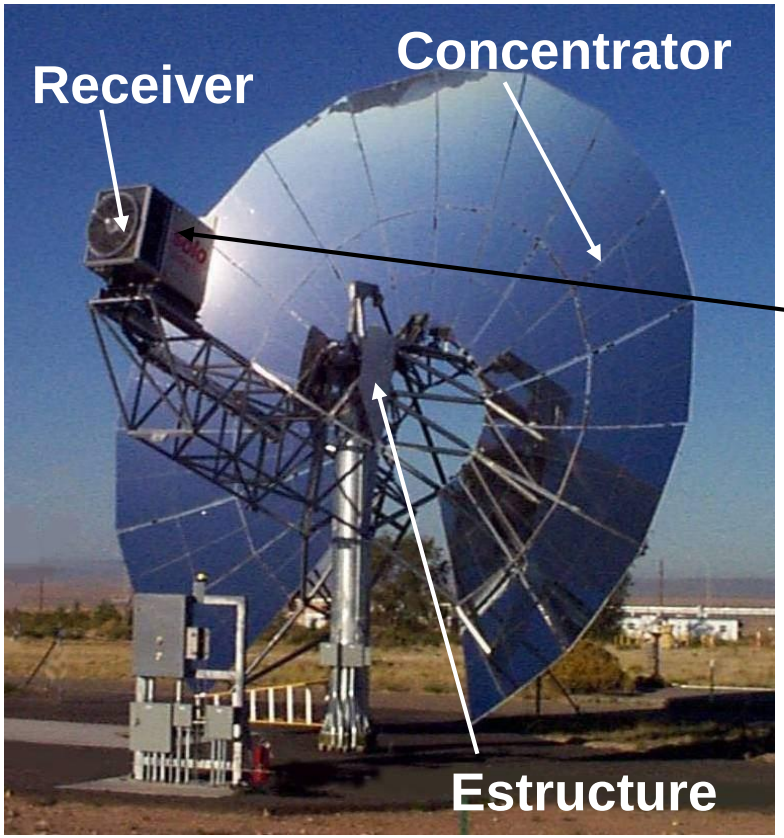


CST Technologies

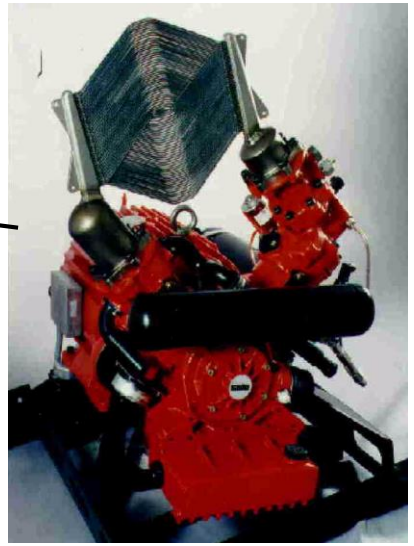
Solar Power Plant with Parabolic Trough Collectors

CST Technologies

Stirling Dish



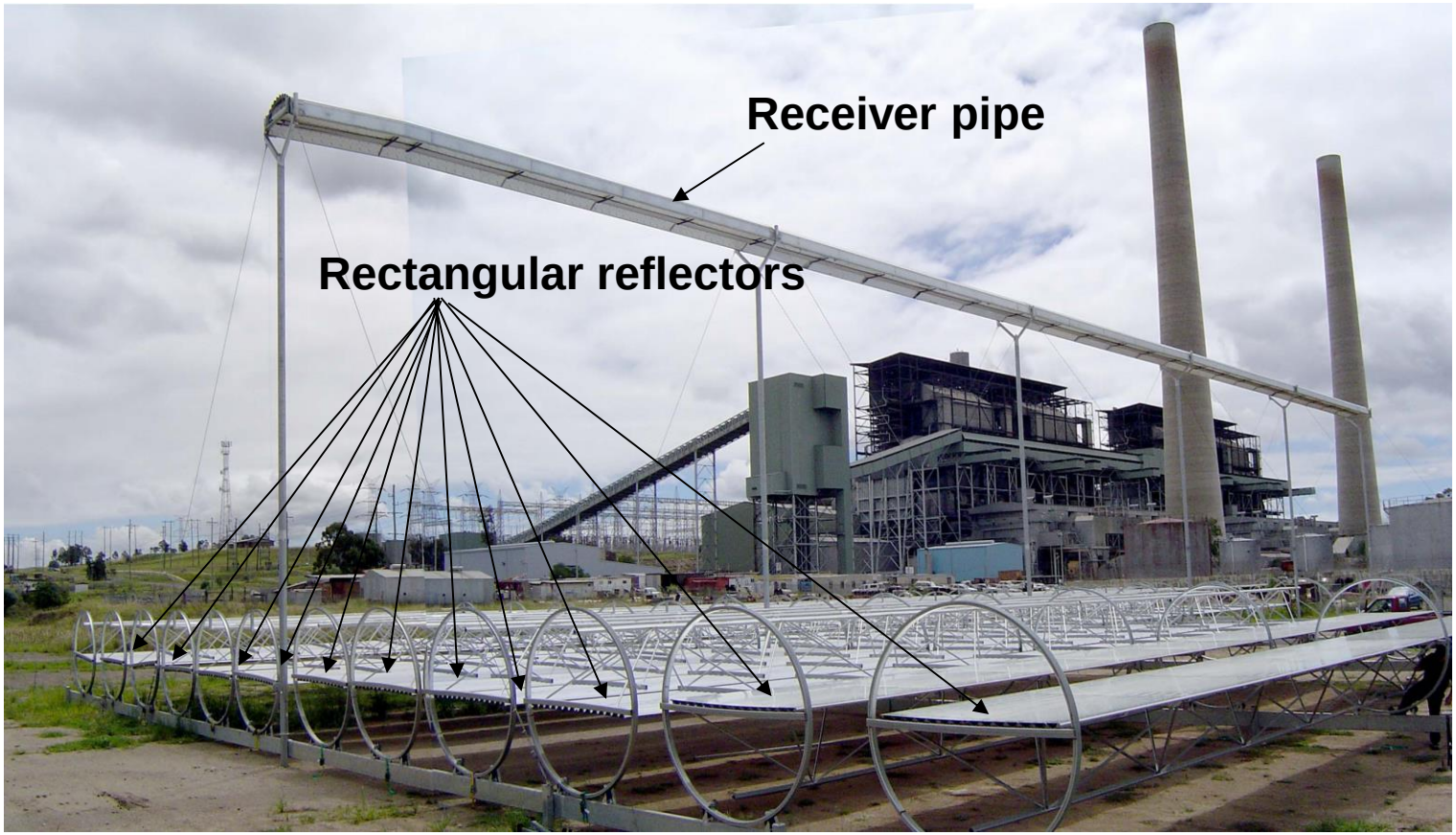
Tipycal Stirling Dish



Stirling engine

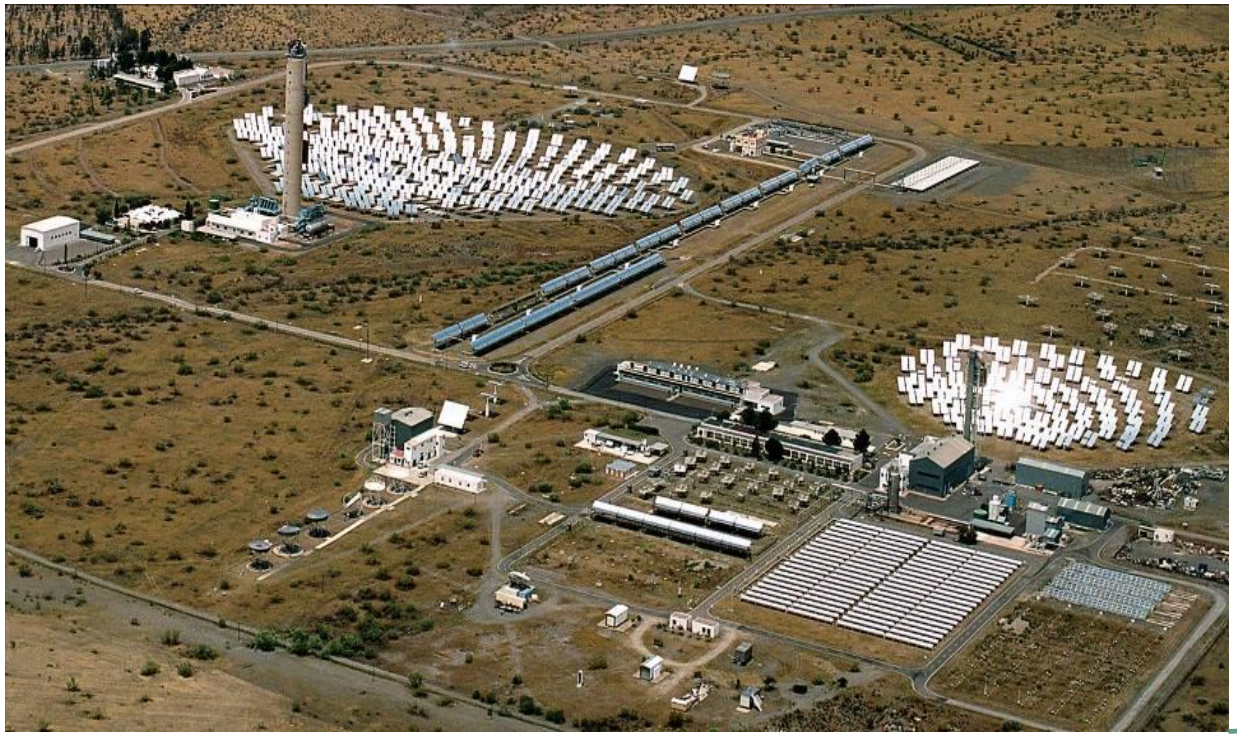
CST Technologies

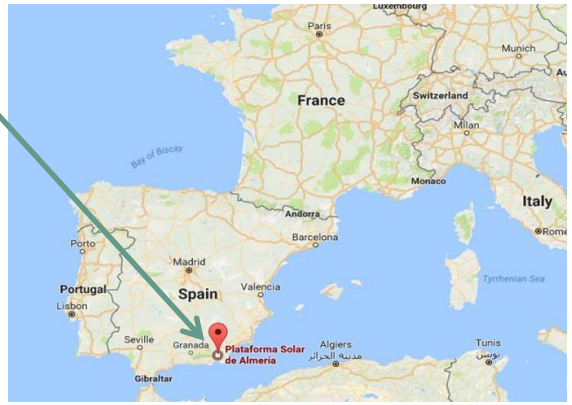
Linear Fresnel Concentrator



PSA: An international R&D Center on CST Technologies

Plataforma Solar de Almería (PSA) is the largest public R&D center in the World devoted to CST technologies





Aerial view of the PSA experimental facilities (www.psa.es)

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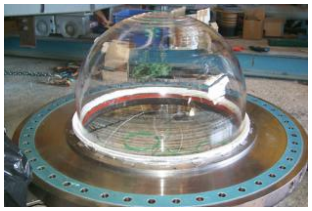
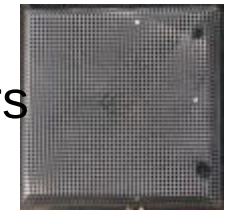
Advanced Materials for CST Systems

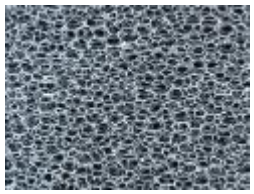
CST systems need advanced materials for extreme conditions in order to reduce cost and/or increase efficiency:

- Special Coatings:
  - Selective coatings for solar receivers
  - Anti-reflective coatings for quartz windows



- Advanced raw materials for Central Receivers





- Advanced materials for thermal storage at high temperatures (>700ºC)

- New working fluids for temperatures >650ºC

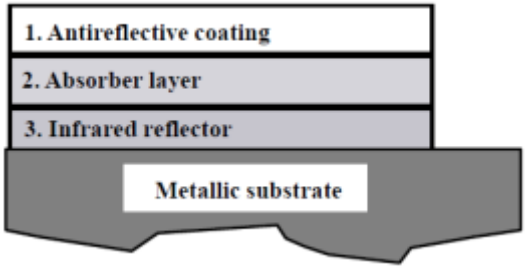
Advanced Materials for CST Systems

➢ Selective coatings for solar receivers

Solar receivers transform the concentrated solar radiation into thermal energy. There are two different groups of receivers

a) Linear Receivers (receivers for parabolic troughs and linear Fresnel concentrators)

- High absorptivity (>95%) and low emissivity ($\varepsilon \leq 0.15$ at 500ºC)
- Stable in hot air at 600ºC and with thermal cycles from ambient to 600ºC
- Solar flux of about 75 kW/m^2



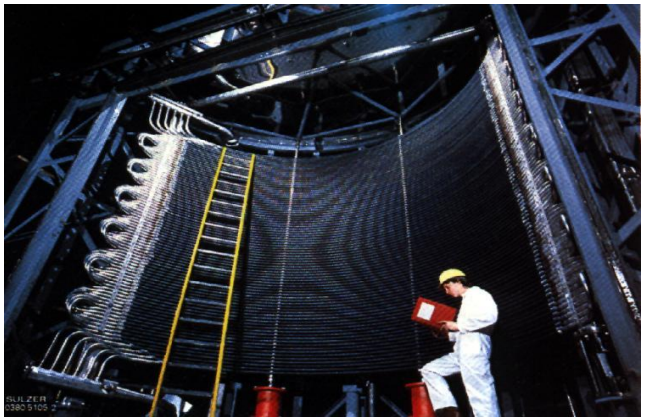
Advanced Materials for CST Systems

- ## Selective coatings for solar receivers

Solar receivers transform the concentrated solar radiation into thermal energy. There are two different groups of receivers

b) Central Receivers (receivers for solar tower systems)

- High absorptivity (>92%) and low emissivity ($\varepsilon \leq 0.35$ at 800ºC)
- Stable in hot air at 800ºC
- Solar flux of about 1 MW/m^2



View of a Tube-bundle solar receiver

Central receiver in operation

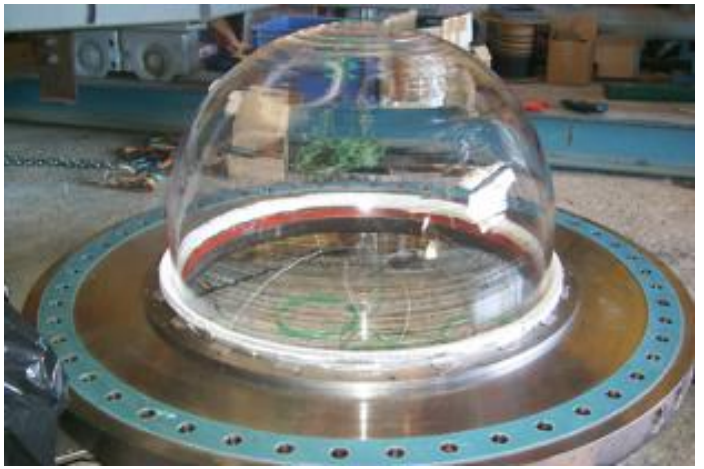
Advanced Materials for CST Systems

➢ Anti-reflective coatings for quartz windows

Quartz windows are commonly used for cavity-type central receivers

Challenges:

- good durability in outdoor conditions,
- easy to produce
- durable at temperatures of about 800ºC.



Typical quartz window used in cavity-type receivers

Advanced Materials for CST Systems

➢ Advanced raw materials for Central Receivers

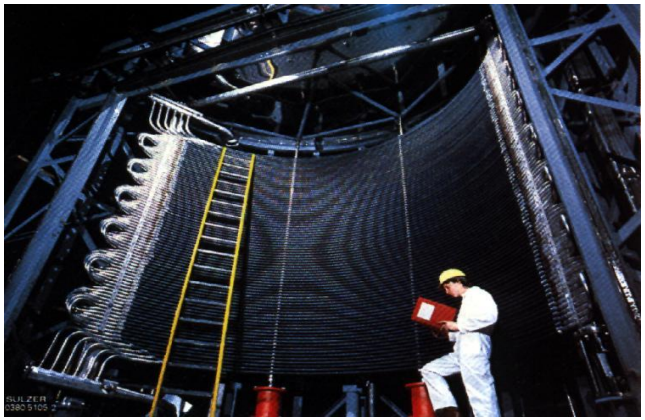
- Receiver types:

  Tube, Volumetric

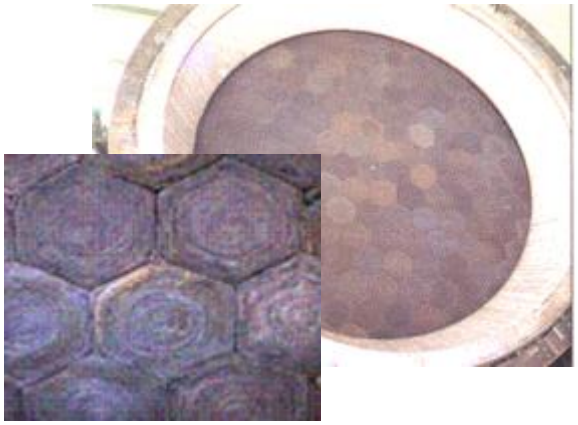
- Receiver raw material:

  Steels: for tube and volumetric receivers

  Ceramics: for volumetric receivers



Tube-bundle solar receiver



Metallic volumetric receiver

Ceramic volumetric receivers

Advanced Materials for CST Systems

➢ Advanced raw materials for Central Receivers

Challenges:

- Working temperatures higher that 1000ºC (steels) or 1200ºC (ceramics)
- Solar fluxes > 1 MW/m^2
- Long durability under thermal cycling
- Good thermal conductivity
- Affordable cost

http://www.abengoasolar.com

http://www.torresolenergy.com

http://aora-solar.com/

Advanced Materials for CST Systems

➢ Advanced materials for thermal storage at T>700ºC

Thermal storage materials currently used:

- Thermal oils (up to 300ºC)
- Molten nitrate salts of sodium and potassium (up to 575ºC)
- Ceramics (alumina) (up to 800ºC, low thermal conductivity)

View of typical 2-tank thermal storage system with molten salts

Challenges:

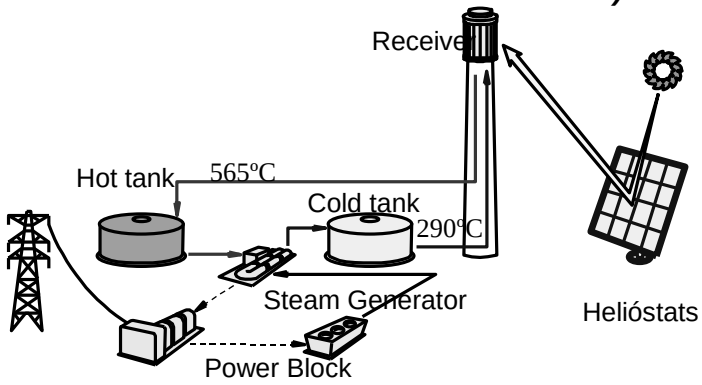
- High heat capacity, thermal conductivity and working temperature
- Low thermal expansion
- Long durability under thermal cycling

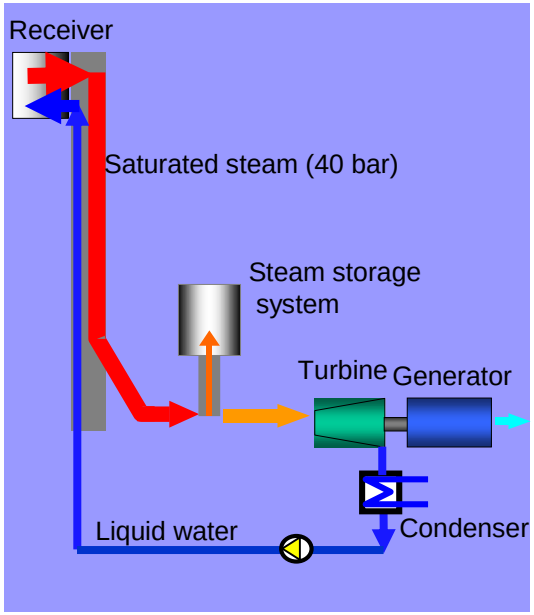
Advanced Materials for CST Systems

➢ New working fluids:

Working fluids currently used:

- Thermal oils (parabolic trough collectors with T≤400ºC)
- Water/Steam (linear Fresnel with T≤300ºC and central receivers with T≤550ºC)
- Molten Salts (central receivers with T≤ 575ºC)
- Air (central receivers with T≤ 800ºC)





Challenges:

- High heat capacity and working temperature
- Long durability under thermal cycling
- Low viscosity

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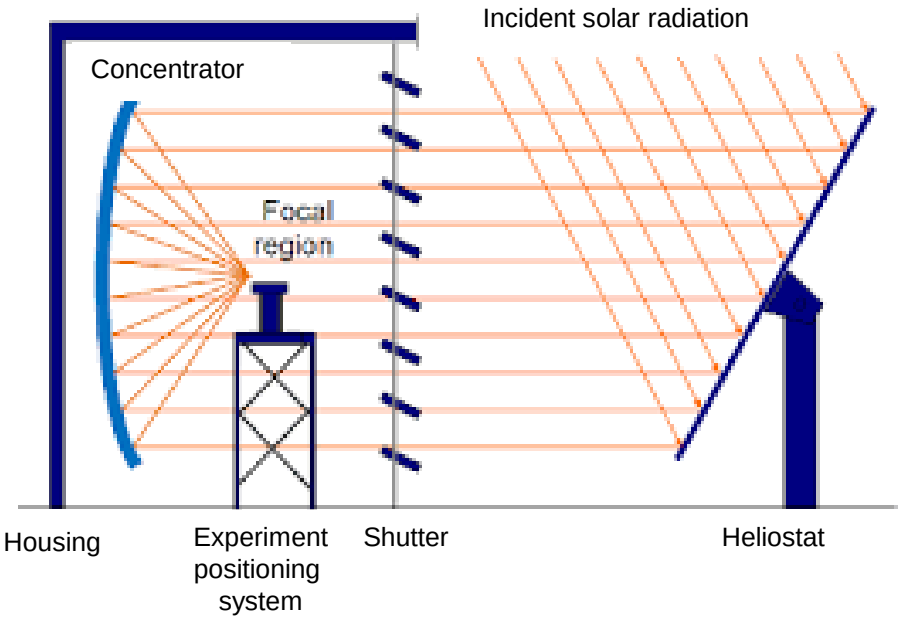
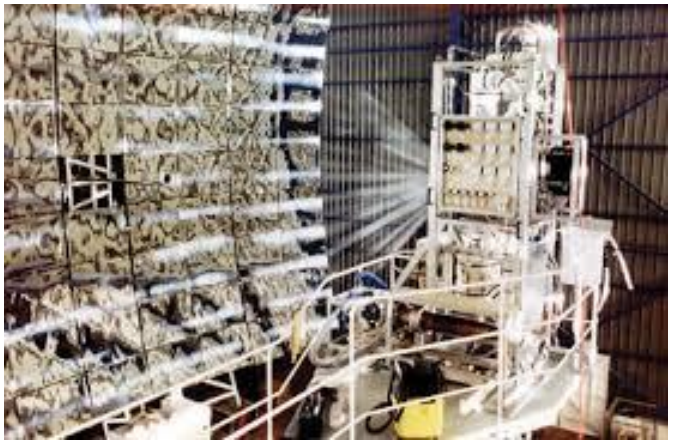
CST Systems for R&D on New Materials

There are two CST systems that are very useful to evaluate the performance of materials in extreme conditions:

- Solar Furnaces



Scheme of a typical Solar Furnace



CST Systems for R&D on New Materials

There are two CST systems that are very useful to evaluate the performance of materials in extreme conditions:

- Solar Furnaces
- Solar Towers

Solar tower system with the heliostats in stand-by position

CST Systems for R&D on New Materials

Use of Solar Furnaces and Towers for materials testing

Direct application of highly concentrated solar radiation to materials

Flux density up to 7000 kW/m^2 (and more)

Very high temperatures >2000ºC

Extreme operating conditions

Materials treatment and caracterization

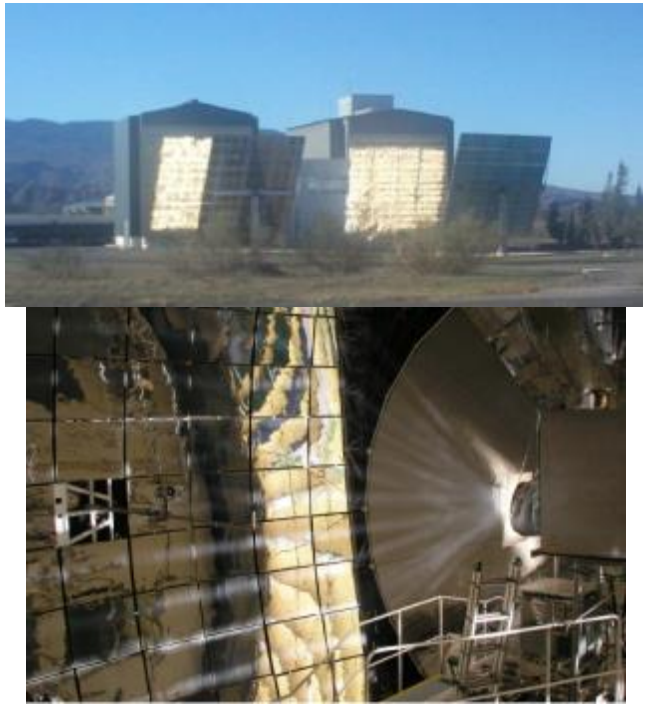
Thermal Shock Tests

Thermal cycling

Tests in air, vacuum and in controlled atmosphere conditions (i.e. Ar, N_2, N_2/H_2)

PSA Solar Furnaces for Materials Testing

SF60

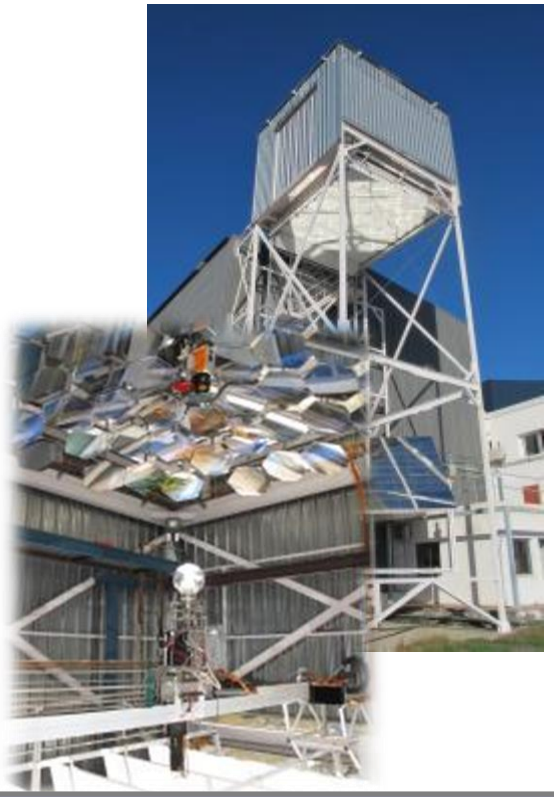


Power	60 kW
Peak Concentration	3000 kW/m^2
Focus Size	Ø 25 cm
Focal Distance	7.45 m

SF40

Power	40 kW
Peak Concentration	7000 kW/m^2
Focus Size	Ø 10 cm
Focal Distance	4.5 m

SF5



Power	5 kW
Peak Concentration	7000 kW/m^2
Focus Size	Ø 2,5 cm
Focal Distance	2 m

PSA Solar Furnaces for Materials Testing

Materials Treatment and High Temperature Solar Heat

Reseach in the field of **surface treatment,** characterisation of metalic and ceramic materials and thermal shock tests.

MiniVac Chamber

- Thermal Shock Tests
- Sintering
- Carburization
- Nitrurization
- Foaming
- Quenching
- Sintering of nano structured materials…

Testing of Concentrating PV Cells

Reseach in the field of **material treatments, solar heat processes at high temperature** and **solar chemistry**

Solar Processing chamber

Fire of ceramic tiles

Flux density up to 700W/cm^2

Temperatures up to 2000 ºC

Solar Fluidized bed

- Steel Hardening and Tempering
- Sintering of aluminium
- Aluminium Foaming
- Reduction of iron oxide to magnetite

Solar Rotary kiln

Solar thermal remediation of contaminated soils

Thermochemical production of H_2

- Catalytic Decomposition of CH_4
- Reduction of ferrites

TESTS IN AIR AND IN CONTROLLED ATMOSPHERE (Ar, N_2, N_2/H_2)

Conclusions

Conclusions

- CST technology needs new Advanced Materials
- Existing CST facilities (solar towers and solar furnaces, mainly) are very suitable for materials testing in extreme conditions

Thank you for your attention !!

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