# next-CSP

## High Temperature concentrated solar thermal power plant with particle receiver and direct thermal storage

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## Deliverable *D1.4*

**WP1 –** Assessment of particle suspension as heat transfer fluid and storage material

**Deliverable title**: Report on tube wall to particle suspension heat transfer for various tube geometry and solid flow conditions

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## Introduction

The solar receiver is most innovative component of the next-CSP. It is composed of forty 3m-long tubes inside which dense suspension of particles (or bubbling fluidized bed) is flowing upward. A particle temperature increase of about 400°C along the tube is expected at nominal conditions: 3 MWth at the receiver aperture and 5 kg/s (18 tons/h) particle mass flow rate. The nominal particle mass flow rate corresponds to 450 kg/h per tube (or 75 kg/m$^2$.s for a 46 mm ID tube). The incident solar flux density varies along the tube height from about 100 kW/m$^2$ to 700 kW/m$^2$ (as reported in RP1).

The key parameter for the design of the solar receiver is the heat transfer properties of the fluidized particle-in-tube system that defines its ability to heat the particle to the nominal temperature under tube wall maximum temperature constraint. The engineering design parameter is the heat transfer coefficient between the tube wall and the particle suspension.

The pilot-scale solar receiver tubes are composed of two sections from the bottom to the top, a 1m-long bare tube section and a 2m-long finned tube section. Consequently, it is necessary to measure the heat transfer properties of the two sections.

The objective of this deliverable is reporting the heat transfer measurements performed with a lab-scale 1m-long single tube solar receiver under similar conditions that designed for the pilot scale solar receiver in terms of tube technology, incident solar flux density and particle mass flow rate. Two experimental campaign have been carried out, one with a bare tube and a second one with a finned tube. This report focuses on the results obtained with the finned tubes because it is the first time that solar experiments were made with such an innovative tube technology (provided by Whittaker Engineering Limited). On the contrary, experiments with bare tubes have been previously performed in the framework of the previous CSP2 FP7 project.

This deliverable presents first the solar experimental setup placed at the focus of the CNRS 1MW solar furnace. The experimental conditions are then detailed. The two next sections address the experimental results achieved with the bare and the finned tube respectively. The latter is more detailed because of the innovative technology involved and of the complexity of the experimental results analysis. Finally, the conclusion summarizes the main findings and suggests some improvements of the technology.

## Conclusion

Heat transfer experiments between upward bubbling fluidized beds and a solar irradiated 1m-long tube has been performed in condition similar to the pilot scale solar receiver to be tested at Themis solar tower:

Olivine mass flow rate: 25 kg/m².s to 110 kg/m².s (nominal 75 kg/m².s)

Solar flux: 230 kW/m$^2$ homogeneous, 520-270 kW/m$^2$, 720-340 kW/m$^2$.

Wall temperature profiles indicate a strong difference between the front side and the back side of the tube. The particle temperature increase range between 100 and 200 °C for the nominal particle mass flow rate and The net power transferred to the particles varies from 11 to about 30 kW in the range of tested parameters.

The heat transfer coefficient was determined at 1200 ± 200 W/m$^2$.K but the large temperature gradients imposed by the concentrating solar heating result in high measurement uncertainty.

Preheating of particles at about 300°C results in mean wall temperature increase and in a decrease of the power extracted by the particles. The number of experiments made with particle preheating are not enough to conclude definitely about the influence on heat transfer coefficient but we have observed a decreasing trend. This variation is in contradiction with data related to classical fluidized bed (increase of h with T) thus indicating that fins efficiency decrease with temperature. As a conclusion, there is room for improving the finned tube technology, fins have been indentified as too long and too thick at the tip.