

Conceptual design of a high temperature conical cavity sodium receiver for solar tower power plants

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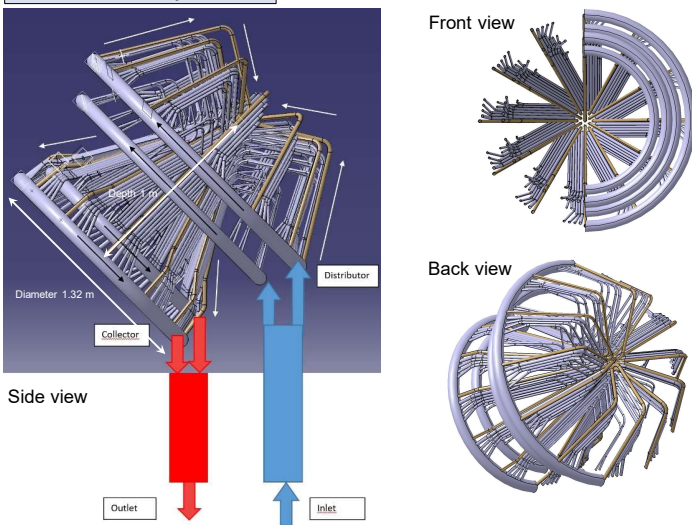
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Introduction and motivation

- Performance improvement of a receiver by enlargement of the receiver area in the region of high solar flux irradiation;
- Conical shape allows the increase of the receiver area in the high solar flux irradiation region;
- Maximization of the solar absorption;
- Free scaling in all directions;
- Drainage solely by gravity;
- Applicable also for other heat transfer fluids, e.g. solar salt.

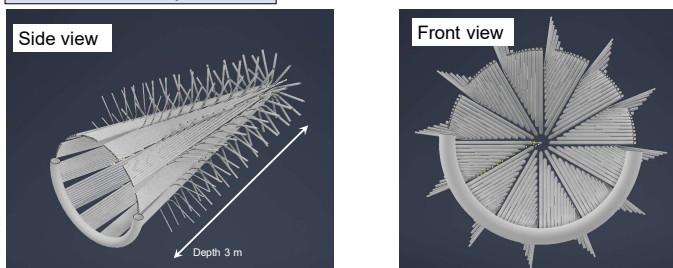
CAD models

Receiver – depth 1 m



Configuration: 12 wings, each wing consists of 2 pipes OD 33.4 mm, 3 pipes OD 25.4 mm, 2 pipes OD 21.3 mm + 3D printed filling part.

Receiver – depth 3 m



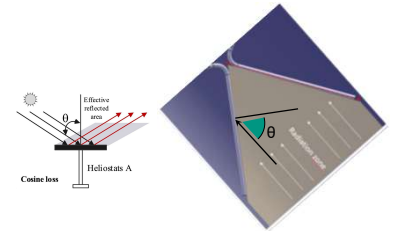
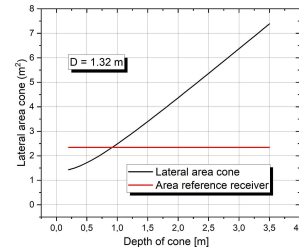
Configuration: 12 wings, each wing consists of 3 pipes OD 25.4 mm, 3 pipes OD 22 mm, 3 pipes OD 18 mm, 3 pipes OD 12 mm + 3D-printed filling part.

References:

J. Coventry, F. Venn, D. Potter et al., SolarPaces 2022, <https://doi.org/10.52825/solarpaces.v1i.728>
G. Linck, Masterthesis KIT, 2025
A. Onea, W. Hering, S. Ulrich et al., SolarPaces 2020, vol. 2445 (1), doi: <https://doi.org/10.1063/5.0087110>

Conceptual design

- Simple and robust design;
- Pipelines arranged in several symmetrical wing configurations;
- Different pipeline diameters considered to adjust the flow rate, in order to obtain a low temperature difference between the pipelines (good temperature uniformization);
- Maximization of the temperature gradient: cold inlet temperature placed in the centre of the receiver, where the solar irradiation flux has a maximum;
- No additional valves required for drainage;
- Free thermal expansion;
- Welding requirements considered in the design phase;
- Gaps to be filled by 3D-printed parts with inner channels, which ensure a sinusoidal longer flow path;
- Expected smaller losses by thermal radiation as for a planar configuration.



CFD models and numerical results

- CFD models: section containing 5 pipes + collector for receiver with depth 1 m and section containing 12 pipes for receiver with depth 3 m;
- ANSYS CFX 2024: conjugate heat transfer model (sodium, Inconel 718);
- Numerical grid: 9.4 mio. cells; $y^+ < 1$ (regions of interest);
- Heat transfer model: thermal energy (turbulence modelling: ω -RS);
- Sodium and material properties implemented as temperature dependent;
- Turbulent Prandtl number:

$$Pr^{*}tb(Na)=0.014 Re^{0.045} Pr^{0.2} \{1-\exp[-1/(0.014 Re^{0.045} Pr^{0.2})]\}$$

Sodium flow rate Section // Total [kg/s]	Heat flux [kW/m²]	Temperature inlet receiver [°C]	Temperature outlet receiver [°C]	Thermal power Section // Total [kW]	Mean velocity inlet receiver [m/s]
Depth 1m					
0.213 // 2.56	750	520	774.8	67.9 // 815.2	0.43
0.213 // 2.56	1000	520	860	90.6 // 1087.6	0.43
0.298 // 3.58	1000	520	763.6	90.9 // 1091.2	0.46

Conclusions

- Innovative flexible conical cavity receiver in development for high temperature CSP plants.
- Increased heat transfer area in the region of the high intensity incoming solar heat flux (e.g. by a factor of 2.1 for a configuration with depth 3 m, compared to depth 1 m).
- Numerical investigations of the receiver model performed up to 1 MW/m².