POLYPHEM
THE FUTURE OF SMALL-SCALE CSP PLANTS

POLYPHEM
Small-Scale Solar Thermal Combined Cycle

D1.2 Report on the solar receiver design optimization

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SUMMARY	This document is the deliverable D1.2 of the project POLYPHEM. It is planned in the framework of the Work Package 01 (R&D ON SOLAR RECEIVER). Task 1.2 of the POLYPHEM project deals firstly with thermohydraulic simulation results of the active part of the solar receiver in order to optimize its design to match with the POLYPHEM project specifications. Secondly, detailed Computer Aided Design (CAD) of the solar receiver have been done thanks to the final design obtained thanks to the simulations. Finally, flow distribution and temperature variations of the global receiver have been estimated. This deliverable presents the main results of the POLYPHEM task 1.2.
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List of Acronyms and Abbreviations

Acronym/abbreviation	Meaning/full text
AALB	Aalborg CSP
ARRA	Arraela S.L.
CA	Consortium Agreement
CAD	Computer Aided Design
CEA	Commissariat à l'Energie Atomique
CFD	Computational Fluid Dynamics
CIEMAT	Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas
CNRS	Centre National de la Recherche Scientifique
CO	Confidential: only for members of the consortium (including the Commission Services)
CSP	Concentrated Solar Power
D	Deliverable
EU	European Union
EURO	Euronovia
FISE	Fraunhofer Institute for Solar Energy Systems, ISE
KAE	Kaefer Isoliertechnik GmbH
M	Month
MS	Milestone
ORC	'Orcan Energy AG' or 'Organic Rankine Cycle'
PU	Public
WP	Work Package

INTRODUCTION

The POLYPHEM project WP01 is dedicated to R&D activities for the development of a high temperature pressurized air solar receiver manufactured by diffusion bonding. The objective is two-fold. The first task is to select an enhanced oxidation resistant Ni-based alloy according to the requirements of the assemblies with a specific focus on the thermomechanical characteristics (task 1.1). The second one is to design the solar absorber and the manifolds with a double and contradictory requirement of low pressure drop and high heat transfer coefficient (task 1.2).

More precisely, the objective of task 1.2 is to optimize the design of the solar absorber and of the manifolds in order to keep the global pressure drop below the requirements of the micro gas turbine and to achieve 80% of thermal efficiency with an increase of the air temperature of 560°C (from 190°C at the inlet up to 750°C at the outlet) under standard solar irradiance. Firstly, thermohydraulic simulations were made in order to reach these objectives. Using the simulation results and the required connections to the micro gas turbine, CADs of the solar receiver modules have been made.

TASK 1.2 CONCLUSIONS

Thanks to simple 2D and 3D thermohydraulic models, geometrical evolutions of the solar receiver allowed to reach the POLYPHEM project specifications for this part of the whole installation.

Using the final modelled design, detailed CAD of the receiver models have been achieved.

Complementary evaluations of the flow distribution and the temperature variations inside the solar receiver show that the selected design is satisfactory.

Annex 1: Explanations of how the 2D model works

The 2D model is built taking into account a slice of the solar receiver along its thickness from the middle of one column of tubes to the middle of the next one as described on Figure 9 for an example of a receiver containing 3 rows of tubes. In this model, the Ni-based alloy tubes inside the receiver are not considered (no gradient temperature in the thickness of the tubes). The insert influence is also added in the model, with appropriate correlations for the heat transfer coefficient.

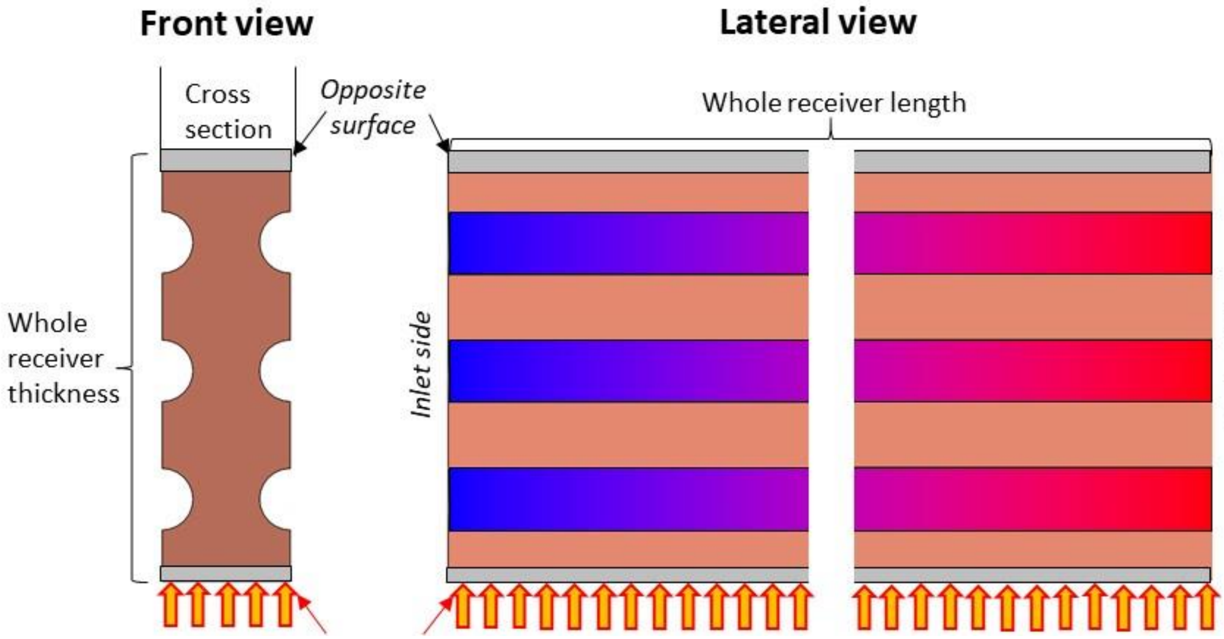

Figure 9: Front view and lateral view of the cross section of the solar receiver taken into account in the 2D thermohydraulic model (example of a 3 row of tubes receiver)

In this model, only the heat flux, which is transferred to the air inside the receiver, is considered. The module is cut into 100 elements along its length.

For one given element, the temperatures and fluxes are presented on Figure 10 for an example of a 3 rows of tubes solar receiver. In a given element, the 2D model works as follows:

- The wall temperature T_{wall} (temperature of the irradiated surface) is calculated so that the heat flux is transferred to the 3 channels.
- The metal temperature between the tubes of the first row T1 is then calculated by conduction from T_{wall}.
- From T1 and using the local heat exchange, fluid temperature in the tubes of the first row T_{fluid} channel 1 is calculated (convection).
- In the next row of tubes, T_2 is calculated from T1 considering that a part of the heat flux has been transferred to the fluid in the first row of tubes.
- The same approach is done for the next rows.
- The temperature of the opposite surface $T_{opposite}$ is considered equal to T_3 as no thermal losses is taken into account.

In the following step, the fluid temperature calculated in the previous steps is considered as fluid inlet temperature in the neighbor element and the procedure is iterated to estimate the wall temperature of this element. The process then takes place as described previously for the next element.

Air physical properties and the local heat exchange coefficient are calculated in each element.

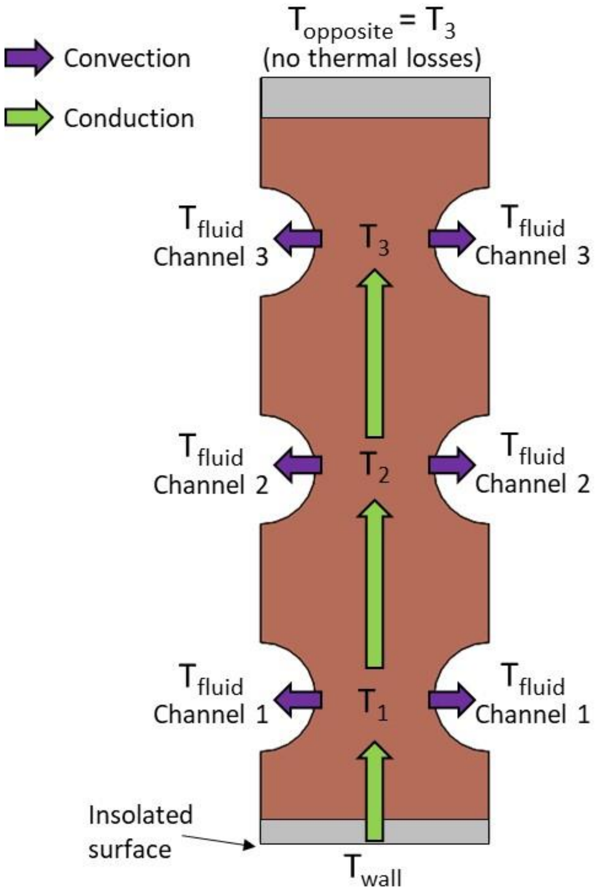

Figure 10: Temperatures and fluxes in one element of the 2D mode for an example of a 3 rows of tubes solar receiver.