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Flow patterns of external solar receivers

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Abstract

The design of the flow paths in solar external-receivers with molten salt as heat transfer fluid is critical to increase the Solar Power Tower (SPT) availability and for a reliable receiver operation. The parameters that affect mostly the start-up and shut-down of the receiver are the Direct Normal Irradiance (DNI) and the sun elevation angle. Furthermore, the feed-pump system requirements and the limiting turbulent Reynolds number also affect the number of operational hours to assure safe receiver operation. Under nominal conditions of operation the most critical factors are the maximum film temperature and the thermal stresses.

In this study, the receiver performance has been analysed during its annual operation. Different flow pattern configurations have been simulated including single or multiple flow paths with or without crossovers. The selection of the optimal configuration has been based on increasing the receiver availability and the global efficiency of the SPT. In the light of the results, during start-up and shut-down the total solar flux intercepted by both flow paths should be approximately the same. However, close to midday to maintain high levels of thermal efficiency a good distribution of the solar flux (peak flux close to the northern panels) is more important.

The most efficient and reliable flow path configuration is a receiver with two modes of operation: a crossover just before the midpoint of the path when the solar flux is low and North–South asymmetric or no crossover when the DNI is high and the peak flux is still asymmetric.

Keywords: Solar external receiver; Molten salt; Flow pattern; Crossover

1. Introduction

In Solar Power Tower (SPT) the solar direct irradiation is concentrated on the receiver by thousands of individually sun-tracking mirrors to reach peak solar flux, up to 1 MW/m^2 (Lata et al., 2008). In the receiver the solar energy is transferred by conduction and convection to the Heat Transfer Fluid (HTF) reaching high temperature that allows generating electricity in a power block.

External central receivers are placed at the top of a tower, configured as a 360° cylindrical tubular receiver, composed by panels made of thin walled tubes. The HTF follows a serpentine path, passing through adjacent up-flow and down-flow panels. The flow pattern configuration can vary from one receiver to another, depending on the ambient conditions and the operation requirements (see Fig. 1). Wagner (Wagner, 2008) analysed eight simple flow configurations, which were later employed in the software design System Advisor Model of NREL (Golden (2015)).

Fig. 1 shows the eight different receiver flow-path configurations proposed by Wagner (Wagner, 2008). Fig. 1(1)–(4) have two symmetric flow paths, in which the HTF is divided into the East and West paths, while Fig. 1(5)–(8) show single flow path configurations, in which the HTF flows

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Nomenclature

HTF	Heat Transfer Fluid
N	North
SPT	Solar Power Tower

Symbols

Cp	specific heat (J/kg K)
C	concentration ratio of flux density (–)
DNI	Direct Normal Irradiation (W/m^2)
N	number of elements (–)
Nu	Nusselt number (–)
Pr	Prandtl number (–)
$\dot{Q}$	heat power (W)
Q	heat flux (W/m^2)
Re	Reynolds number (–)
S	surface area (m^2)
T	temperature (°C)
UTS	ultimate tensile strength (Pa)
dt	tube diameter (m)
f	Petukhov coefficient (–)
$\dot{m}$	mass flow (kg/s)
v	salt velocity (m/s)

Greek letters

ΔP	pressure drop (Pa)
ε	Nusselt coefficient for transition regime (–)
η	receiver thermal efficiency (–)
μ	dynamic viscosity (Pa/s)
ρ	salt density (kg/m^3)
σ	thermal stress (Pa)

Subscripts

amb	ambient
e	east
film	film
fp	flow path
in	inlet
int	internal
l	laminar
min	minimum
p	panel
rec	receiver
salt	salt
t	turbulent
tubes	tubes
w	west
we	external wall

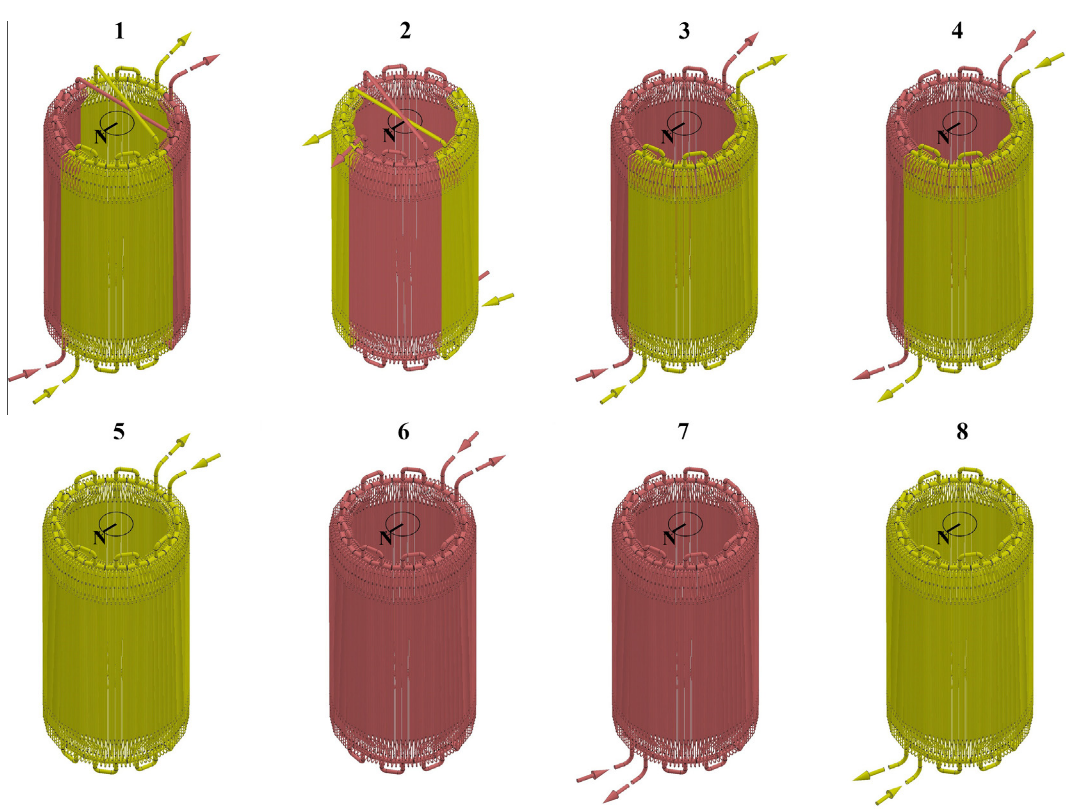

Fig. 1. Receiver scheme for the eight flow pattern configurations proposed by Wagner (2008).