Simulation Heat Transfer Fluids Efficiency and Molten Salts in Heat Collecting Elements in Concentrating Solar Power

N. Olmedo-Torre(1), J. Ivern Cacho(1), B. Amante García(2), O. Farrerons Vidal(1)

(1) Escola Universitària d'Enginyeria Tècnica Industrial de Barcelona. Universitat Politècnica de Catalunya·BarcelonaTech
+34934137376, olmedo@ege.upc.edu

(2) Escola Tècnica Superior d'Enginyeries Industrial i Aeronàutica de Terrassa. Universitat Politècnica de Catalunya·BarcelonaTech

ABSTRACT

This work proposes a useful tool for simulating the efficiency of different HTFs and molten salts when circulating through a section of heat collecting elements in parabolic trough systems for concentrating solar power. By means of the *SolidWorks®* program and the *FlowSimulation®* complement, flow is simulated along a section under real operating conditions as well as the heat loss of the HTF when circulating through a network of tubes in the solar field. This work may prove useful for exploration of the use of new heat-transfer fluids in heat collecting elements. Different publications in the literature have been taken into account for the simulation of the model presented herein.

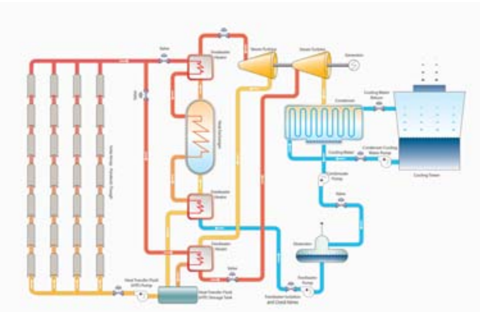

Image 1. Concentrator and heat collecting elements. Process Diagram.

INTRODUCTION

The existing capacity throughout the world of Concentrating Solar Power (CSP) (Parabolic Trough Systems, Linear Fresnel Reflector Systems, Power Tower Systems and Dish/Engine Systems) increased by 50% during the period 2008 to 2013. The accumulated power of all CSP plants as of February, 2016, was 4.749 GW, with the expectation that it would reach an installed capacity of 10 GW in 2018, as compared with the 294 GW of installed capacity of the photovoltaic systems forecast for 2016 and the 450 GW estimated for 2018. CSPs with an estimated power of 1.18 GW are at present under construction and a further 4.17 GW in process of development.

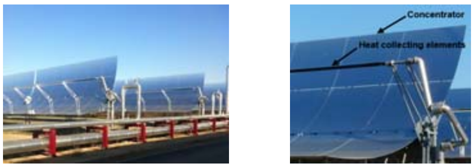

Image 2. Concentrator and heat collecting elements.

EXPERIMENTAL

The tube is an assembly consisting of five parts: an inner metallic Tube (DIN 1.4541), an outer envelope (Glass), a metallic bellows, and two seals at the ends of the bellows connecting it with the metallic tube (both AISI 304).

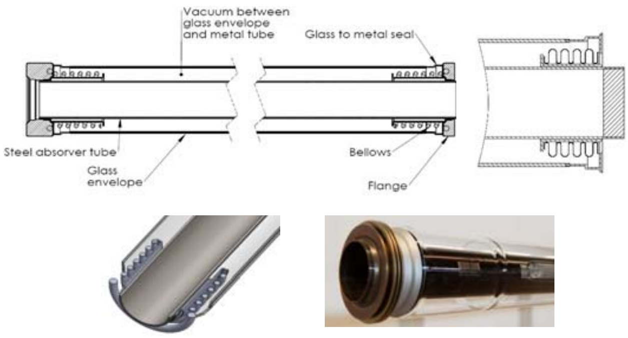

Image 3. Heat collecting element and details.

The SolidWorks® and FlowSimulation® program tools are used to simulate the real running conditions in a section of the heat collecting element.

Physical properties	Other initial conditions
Thermal conductivity (m·K). Density (kg/m^3). Specific heat (J/kg·K). Dynamic viscosity (Pa·s).	Roughness. Heat transfer coefficient. Mass flow rate circulating (6.4 kg/s). Length (4 m). Exterior diameter metallic tube (7.0 cm). Glass envelope (12.5 cm).

The oils chosen are
Therminol VP1, Syltherm 800, Dowtherm A, Therminol 59 and Marlotherm SH

The salts chosen are
Hitec XL, Solar Salt, VP1, Dowtherm Q and Dowtherm RP.

Data analyzed fluid are:

Heat loss (W) - Loss of charge (Pa) - Reynolds number (Re) - Velocity (m/s) - Heat lost by conduction at the ends of the tube (ΔºC).

Static pressure at the entrance to the tube is set to 15 bars. Temperature at the point of entry is 563 ºK. Solar radiation is simulated by projecting a heat source of 15.140 W. The atmospheric conditions: Temperature 293 ºK and atmospheric pressure 101.350 Pa.

RESULTS AND DISCUSSION

The analysis shows that the fluids undergo a loss of pressure due to friction with the walls of the tube, both at the connection and in distribution. Furthermore, both density and viscosity drop as the temperature increases. The maximum temperature values are found at those areas of the fluid that are closest to the walls of the tube, where heat absorption by convection occurs. The increase in mean temperature at the entrance and exit is equal to 0.9965 ° C. The Reynolds number indicates that this is a turbulent flow, which is important because it favours heat transfer by convection between the inner wall of the tube and the fluid.

Therminol 59 has a greater useful temperature range and reaches 315 °C with stability. This fluid undergoes a lower temperature increase because of a greater specific heat.

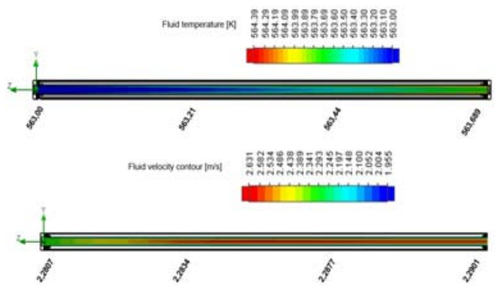

Image 4. Temperature gradients and velocity in the immediate surroundings for the Therminol VP-1 in the collector-receiver tube.

Image 4 shows the temperature gradients and velocity in the immediate surroundings for the Therminol VP-1.

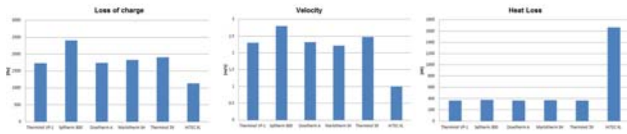

Image 5. Loss of Charge, Velocity and Heat Loss of different fluids.

It is observed that Dowtherm A has properties very similar to those of Therminol-VP1. The low temperature increase is the most significant difference due to the slightly higher specific heat of this fluid. The Marlotherm SH is a fluid whose maximum working temperature is 350 ° C, which constitutes a disadvantage when compared with the fluids previously studied. It does not require a high pressure to prevent evaporation, and its steam pressure is lower than one atmosphere at 350 ° C.

Fluid	Thermal losses [W]	Pressure losses [Pa]	Δ Temperature [C]	Nº Reynolds [Re]
Therminol VP-1	365,4700547	1728,2246	0,9965	533859,0995
Syltherm 800	376,1222442	2401,8008	1,0998	247051,9373
Dowtherm A	365,326022	1736,2723	0,9779	549860,6201
Marlotherm SH	369,4603667	1830,0148	0,8906	306149,8879
Therminol 59	365,9165757	1902,6968	0,8817	467094,8779
HITEC XL	1661,328789	1137,0332	1,4829	47785,55438

Table I. Simulation variables of the fluids

Result	Out temperature	In temperature	Temperature increase	Thermal losses
	ºC	ºC	ºC	W
Theoretical	291,0056	290,0000	1,0056	365,2511
Simulation	290,9965	290,0000	0,9965	365,4701
Relative error [%]			0,9071	0,0599

Table II. Related estimated errors

Relative errors are taken into account in the results obtained as compared against the simulation conducted with the Burkholder and Kutscher method, and are lower than 1 %. Table II.

CONCLUSIONS

- The Therminol VP-1 and Dowtherm synthetic oils are the most efficient due to their broad range of working temperature, low heat loss and loss of charge, low viscosity and an affordable cost.
- The fluids composed of silicones, such as Syltherm 800 or the molten salts, are less prejudicial for the environment than organic oils and does not require an auxiliary heating system because of its low point of solidification.
- Molten salts provide an option for us in HTFs, where a heat exchanger between the oil and the salts is unnecessary and thereby results in a reduction of plant operating costs as well as improving its competitiveness.
- Future work includes the study of improvements in geometry and in the dimensions of the tubes in order to reduce heat loss through optical effects.

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