# THERMAL SIMULATION OF A CONCENTRATOR PIPE COMPOSED WITH NORMAL RADIATION DISTRIBUTION

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## ABSTRACT

The generation direct of steam in the solar concentrators of the thermosolar plants have to be structural problems caused for the deflection of the pipes concentrators due to temperature gradients in the radial and angular directions. In this work is made thermal analysis to an absorber pipe of walls composed copper steel, it is modeled the heat transfer in stable state and transient state; the mathematical models obtained are solved with the finite differences technique. In the results are presented the radial and angular temperature distributions, also is determined the time in which the system reaches the stationary state under the studied conditions. The absorber pipe is a system of composed walls, formed by commercial copper pipes type k of 61.849 and 66.675 mm internal and external diameter respectively and a steel pipe schedule 160 of 66.700 mm of internal diameter and, 88.900 mm of external diameter, whose composition is Copper (20%)-Steel ( 80%).

## INTRODUCTION

One of the limiting of the thermosolar plants of concentrators of parabolic channel is due to the efficiency decrease in the exchange of the energy for the use of thermal oils in heat exchangers, due to the fact that they can not be reached increased temperatures by the low boiling temperatures of oils. The direct generation of steam in solar concentrators, avoid the use of heat exchangers, also the costs of operation are reduced. As consequence of this problem are generated studies of new materials that they could support the thermal efforts and of pressure in the change phase of the work fluid. This originates our attention in accomplishing a study routed to employment concentrator pipes compounds of copper and steel that could sustain high pressures and temperatures, to be used in the generation direct of steam in thermosolars plants. The mathematical models as the accomplished laboratory experiments about the gradient circumferential of temperature accomplished them by Odeh, (e.g. Odeh et al., 1998). show that the difference of temperatures between the high and low parts of the absorber pipe is of 60 °C to an pressure of 60 bar, when has a flow of inverse radiation. Some similar results were obtained by Hahne (e.g. Hahne et al., 1997), for different bulk flows. Almanza (e.g. Almanza et al.1994) have studied the behavior of the receiver of parabolic channels supplying cold water to the receiver steel pipe (diameter =2.54 cm) was generated a deflection in the absorbers pipes, this deflection advanced as a wave from the entry until the exit, having a deflection approximately of 6.5 cm in the center of each section

(2.9 m of length) of the parabolic trough collector (14.5m of long between 40 and 60 °C in the circumferential direction).

## METHODOLOGY

The mathematical model in cylindrical coordinated is obtained like an analysis in a absorber pipe of wall composed bimetallic of a parabolic trough collector, in the position of the problem are made the following considerations: a) two-dimensional heat flow in stationary state to trough of the wall of concentrator pipe, b) flow biphasic (liquid - steam) inside of the concentrator pipe, c) flow of normal radiation d) symmetry axial plane, f) anisotropic material. As the system has symmetry in the axial axe. Figure 1. The Figure 2 shows the flow normal radiation,

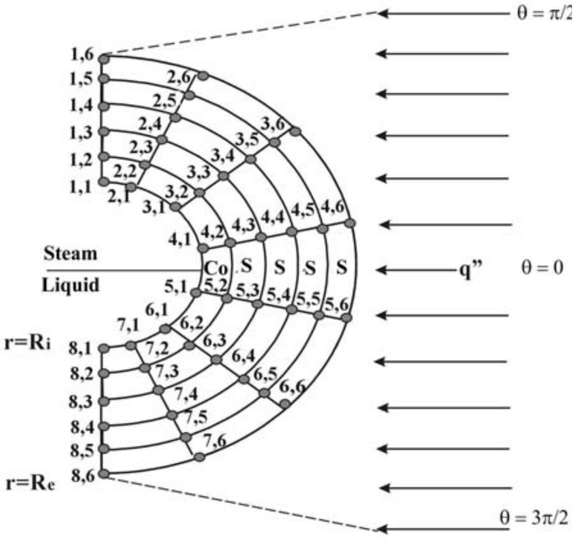


Figure 1: Position of the system in operation.

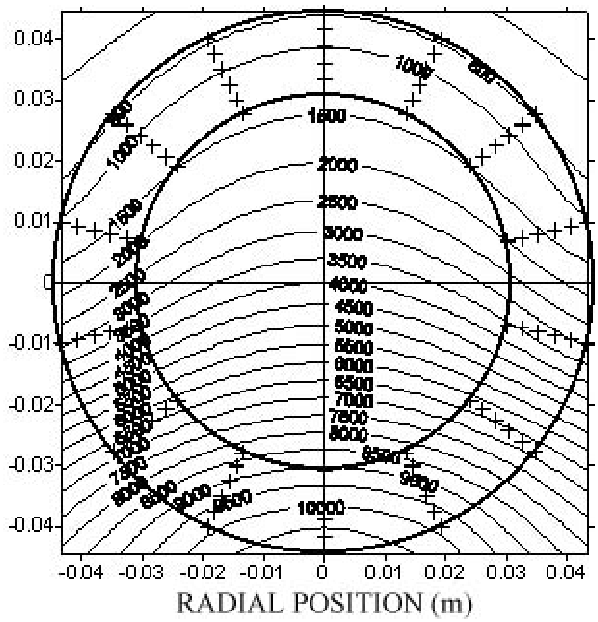


Figure 2. Solar radiation around absorber pipe (W/m$^2$)

To have differential energy balance in the pipe absorber of wall composed of a concentrator of parabolic trough channel (to see Figure. 1) is obtained the mathematical model to calculate the temperatures distribution of a two-dimensional system in transient regime, the one which is expressed as continues:

$$\frac{1}{r}\frac{\delta}{\delta r}\left(kr\frac{\delta T}{\delta r}\right)+\frac{1}{r^2}\frac{\delta}{\delta \theta}\left(k\frac{\delta T}{\delta \theta}\right)=\rho C_p\frac{\delta T}{\delta t} \qquad (1)$$

Boundary conditions used:

$$\theta=\frac{\pi}{2} \text{ and } \theta=\frac{3\pi}{2} \qquad \frac{\delta T}{\delta \theta}=0 \qquad (2)$$

$$r = Re \qquad -k\frac{\delta T}{\delta r}=q'' \qquad (3)$$

$$r = Ri \quad \text{and} \quad 0 \le \theta \le \frac{\pi}{2} \qquad -k\,\frac{\delta T}{\delta r} = h_g\,(T_g - T_w) \qquad (4)$$

$$r = Ri \quad \text{and} \quad \frac{3\pi}{2} \le \theta \le 0 \qquad -k\,\frac{\delta T}{\delta r} = h_g\,(T_g - T_w) \qquad (5)$$

The distribution of solar radiation to absorber pipe:

$$\begin{cases} 0 \le \theta \le \pi/2 & q''(\theta) = 800 W/m^2 \qquad (6) \\ 3\pi/2 < \theta \le 0 & q''(\theta) = 11250 \sin(\theta - \pi/2)\ W/m^2 \qquad (7) \end{cases}$$

To accomplish the thermal analysis of the pipe absorber are taken the following values:

- The pipe absorber built only of steel has a smooth internal surface, with a thermal conductivity of 52 $Wm^{-1}K^{-1}$, density of 7,817 $kgm^{-3}$ and a calorific capacity of 446 $Jkg^{-1}K^{-1}$.
- The pipe absorber compound of Copper - Steel, the copper pipe has a smooth internal surface with a thermal conductivity of 401 $Wm^{-1}K^{-1}$, density of 8,933 $kgm^{-3}$ and a calorific capacity of 385 $Jkg^{-1}K^{-1}$; the copper pipe is covered in their foreign part by a steel pipe with the cited characteristics previously.
- Considered a solar radiation of the Mexico City of 800 $Wm^{-2}$ and the maximum radiation of 1,1250 $Wm^{-2}$.
- Saturation condition of the water: 160 bar (623K).
- Liquid level 50%, constant.

## RESULTS

The numerical analysis was accomplished for a absorber pipe compound whose wall is composed of 20% Copper and 80% Steel. Using the discreet relationships for the stable state developed by Valdés (e.g. Valdés et. al.1998) and transient.

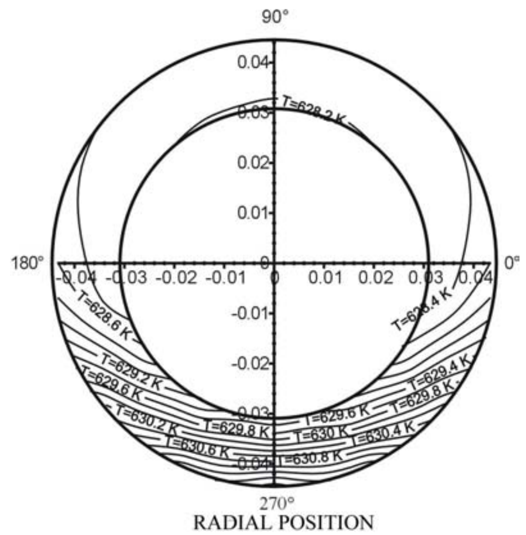

Figure1: Distribution of temperature to copper-steel pipe t = 0sec.

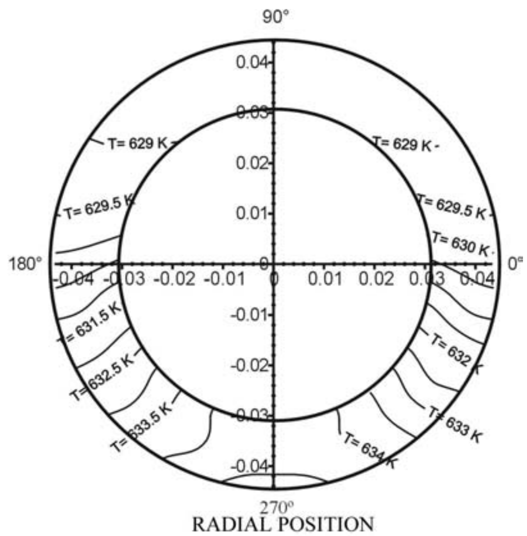

Figure 2: Distribution of temperature to copper-steel pipe t = 10sec

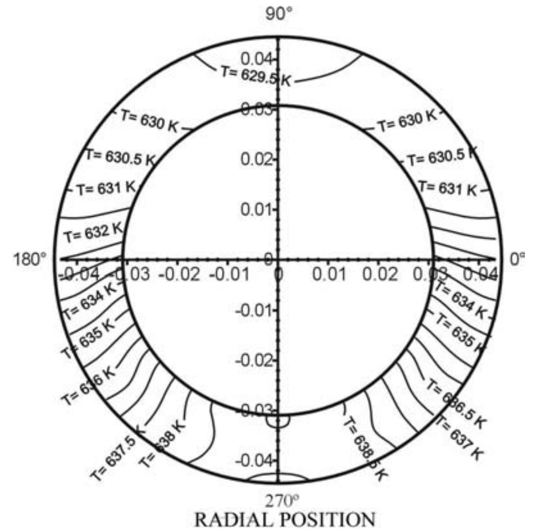


Fig. 3: Distribution of temperature to copper-steel pipe t = 20sec.

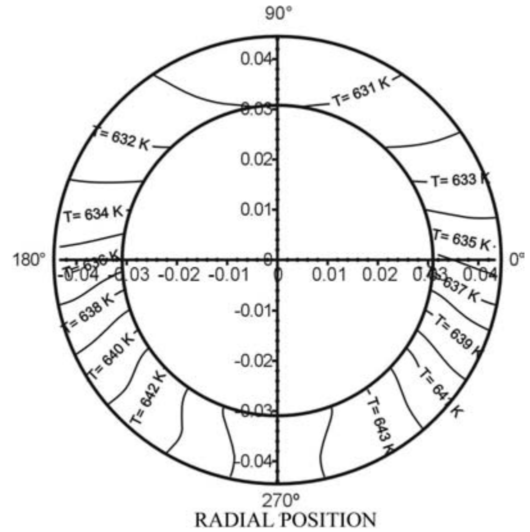


Fig. 4: Distribution of temperature to copper-steel pipe t = 30sec

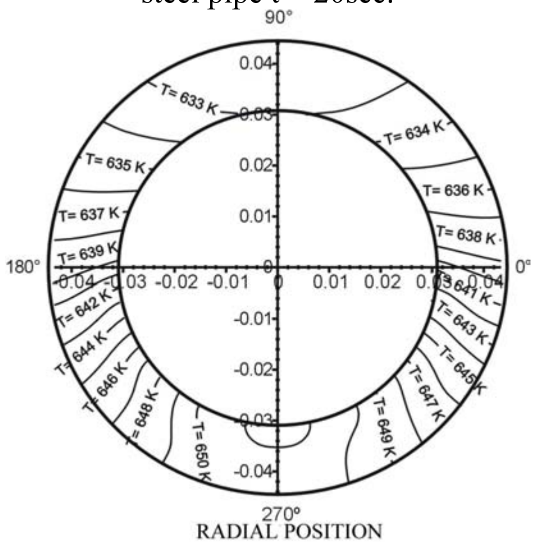


Fig. 5: Distribution of temperature to copper-steel pipe t = 40sec.

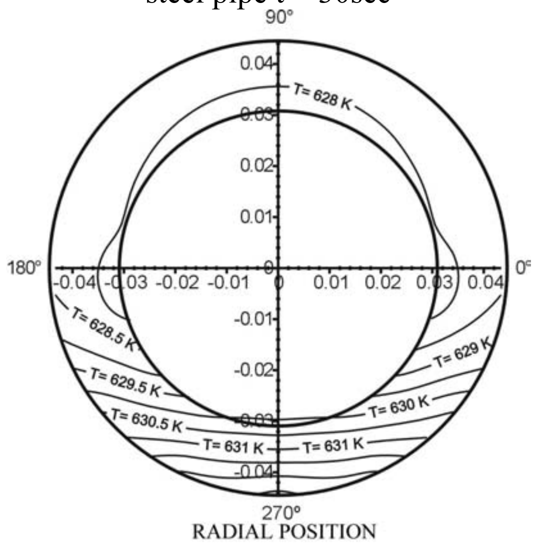


Fig. 6: Distribution of temperature to steel pipe t = 0sec

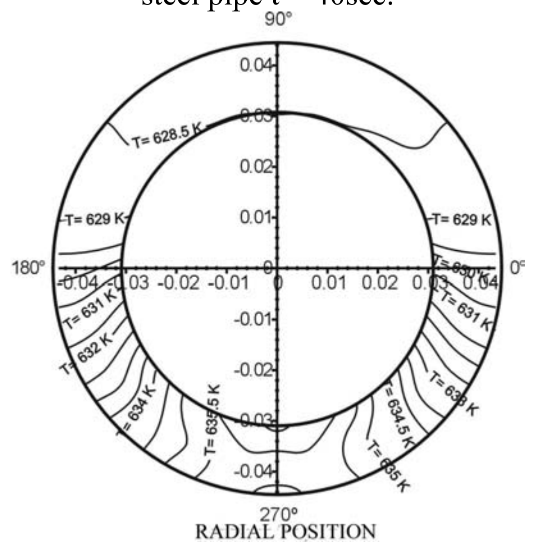


Fig. 7: Distribution of temperature to steel pipe t = 10sec

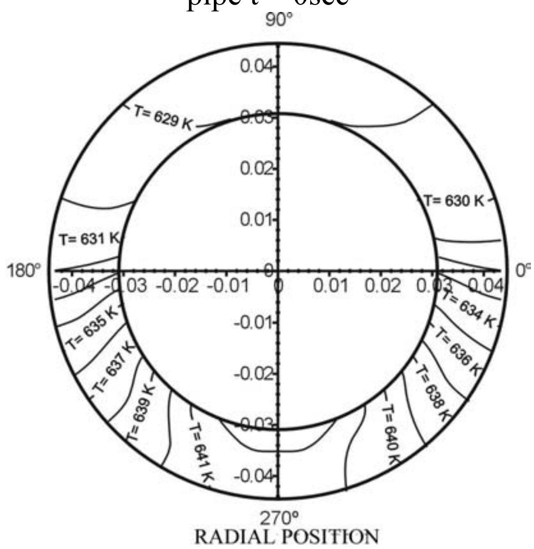


Figure 8: Distribution of temperature to steel pipe t = 20sec

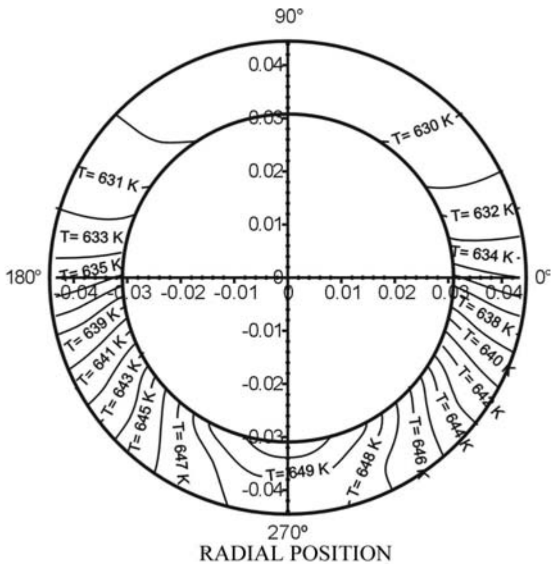


Figure 6: Distribution of temperature to steel pipe t = 20sec

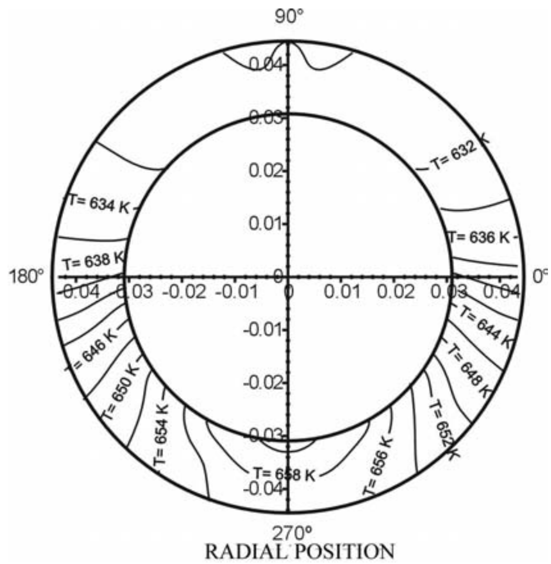


Figure 6: Distribution of temperature to steel pipe t = 30sec

## CONCLUSIONS

- The proposal of a absorber pipe compound is justified fully to the light of the effected thermal analysis where are described the different thermal behaviors adopted by the pipe, as conclusion of this work are established the following points:

- The pipe composed reaches in smaller time the stationary state (30 seconds).

- The thermal behavior changes more severe for both pipes was in the region about the liquid interface steam and the lower part of the pipe.

- The steel pipe after of the transient state maintains an extreme behavior with violent changes of the temperature gradients in 30% of the wall of the pipe, reducing in the stationary state.

- Under stationary state conditions are maintained regions about the interface with important temperature gradients for the steel pipe and 50% smaller for the pipe composed.

## NOMENCLATURE

| | |
|---|---|
| $C_p$ | Calorific capacity |
| hl | Convective coefficient of heat transfer liquid |
| hg | Convective coefficient of heat transfer steam |
| k1 | Thermal conductivity |
| $\delta\theta$ | Angle position increase |
| $\delta r$ | radial position increase |
| $\delta T$ | Temperature increase |
| $\delta t$ | Time increase |
| Re | External radio of absorber pipe |

Ri Internal radio of absorber pipe
r Radio
T Temperature
$T_l$ Liquid phase temperature
$T_w$ Wall Temperature

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