Bulletin of the *Transilvania* University of Brasov • Vol. 2 (51) – 2009
Series I: Engineering Sciences

DETERMINING THE DISTRIBUTION TEMPERATURE FIELD AROUND THE STEAM INJECTING WELLS BY USING THE ECLIPSE™ SIMULATOR

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Abstract: *The paper is integrant part of a study regarding the efficiency of the steam injection used as a thermal recovery method. The main scope of this paper is to determine the distribution of the temperature field around the steam injection wells and to show, qualitatively, the phenomenonas that are taking place into an oil reservoir in the case of thermal stimulations. In this scope it was build a simulation model of a reservoir suitable for thermal stimulation: high values of oil viscosity (thousands and tens of thousands of cP), porosity (over 25 %), permeabilities (hundreds and thousands of mD) density (more than 945 kg/m*^{3}*), relatively shallow reservoirs (up to 900 m), low values of gas oil ratio and formation volume factor. The simulation grid is Cartesian corner point gird, and the exploitation method (solution) is an experimental five spot pattern. The simulator used is ECLIPSE compositional thermal E500 produced and commercialized by Schlumberger company.*

Key words: *steam injection, distribution temperature field, ECLIPSE simulator*

1. Introduction

The main focus of this paper is to show the temperature's field distribution in the case of a well who is used for cyclic steam injection. In order to evaluate the efficiency of a well that is stimulating a reservoir by thermal method, it was selected a sector of reservoir, with a high density of grid around the well.

2. Short Theory

In the case of the movement of the monophase or multiphase fluids in porous media associated with a variable temperature field, the heat transfer can be performed by conduction, convection or radiation. Based on the electromagnetic phenomenon that is taking place at atomic level, it can be assessed that the heat transfer by radiation within porous media can be neglected. Considering a infinitesimal parallelepiped control volume, within a porous media where the fluid movement is taking place, into a variable temperature field, with inter-phase mass transfer, the microscopic equation of heat conservation can be enounced as follows: *the heat entered in this volume through the domain boundary minus the heat evacuated through the same boundary*

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plus the heat due to sources (injection or producing wells) plus heat resulted from chemical equations plus the heat transferred between phases plus the heat resulted due to phase transformation is equal to the heat accumulated within a specified time interval.

This reservoir is called generically AA. This reservoir has no active aquifers. The shape is presented in figure 1.

The properties of the reservoir are presented in table 1.

$$\frac{\partial}{\partial x}\left(\lambda\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(\lambda\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(\lambda\frac{\partial T}{\partial z}\right)-\left[\frac{\partial}{\partial x}(\rho c v_x T)+\frac{\partial}{\partial y}(\rho c v_y T)+\frac{\partial}{\partial z}(\rho c v_z T)\right]= \quad (1)$$

$$=\frac{\partial}{\partial t}\left[m\rho c+(1-m)\rho_r c_r\right]T$$

If it is considered a particular case when the sources (injectors or producers of the warm / hot fluid) and the chemical reactions are missing, the previous statement can be modeled by the above equation (1), where:

λ coefficient of heat transfer by conduction,

ρ, c, v are density, fluid specific heat and fluid velocity,

T – temperature,

m – porosity,

ρ_r, c_r are density and rock specific heat,

t – time;

x, y, z Cartesian coordinates.

In order to model the fluid movement within the porous media, apart from the equation of heat conservation are needed the Darcy equation and mass conservation equation. Those equation are forming an equation system and it's coefficients are depending on pressure and temperature. In most of the cases this system of equations can only be solved numerically, by using different numerical techniques: finite differences, finite elements, and finite boundary elements.

3. Reservoir Description

The reservoir is sandstone, with some intercalations of clays, anticline with a depth from 500 m to approximate 800 m.

The AA reservoir's main properties Table 1

Property, MU	Value/Range
Porosity, %	5 – 34
Permeability, mD	200 – 1200
Net to Gross, %	0 – 100%
Irreducible water saturation, %	20 – 22 %
Temperature gradient, C/100m	3

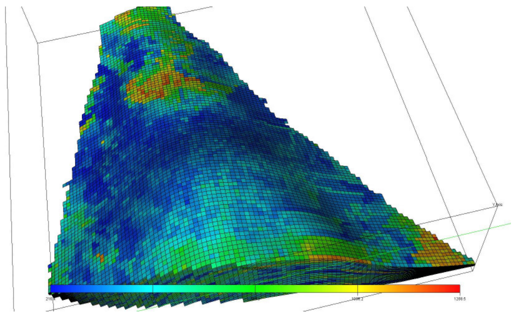

Fig. 1. *The AA reservoir*

4. Fluid Properties

The reservoir contains unsaturated oil (no liberated gas), slightly over pressured with the pressure measured at 600 m TVD of 70 bars. The oil's density is around 975 kg/m^3. The oil is characterized by the critical parameters: critical pressure 14.5 bars and critical temperature 590 °C. These values can be observed also in the phase's envelope in figure 2. For the simulation purposes, the fluid is characterized by two components, one merging the light components, called **Light** and another one, merging the heavy components, called **Heavy** with molecular mass of 30 kg/kmol and 400 kg/kmol respectively.

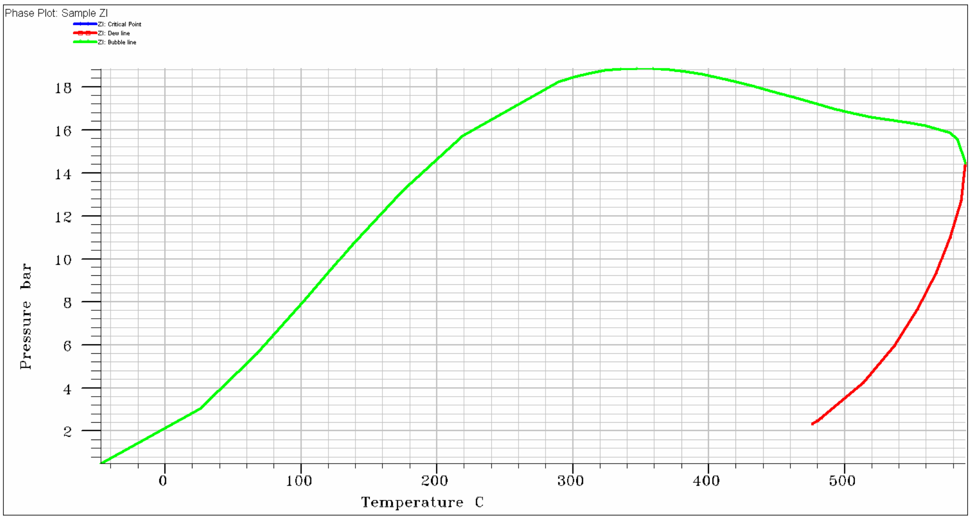

Fig. 2. *Phases envelope*

The oil's viscosity is shown in figure 3 and it can be seen that at low temperatures the oil is highly viscous – 800 cP, but by increasing the temperature, the viscosity drops, so around 80 C the viscosity is around 4 cP. This is shown that the reservoir can be produced by thermal methods.

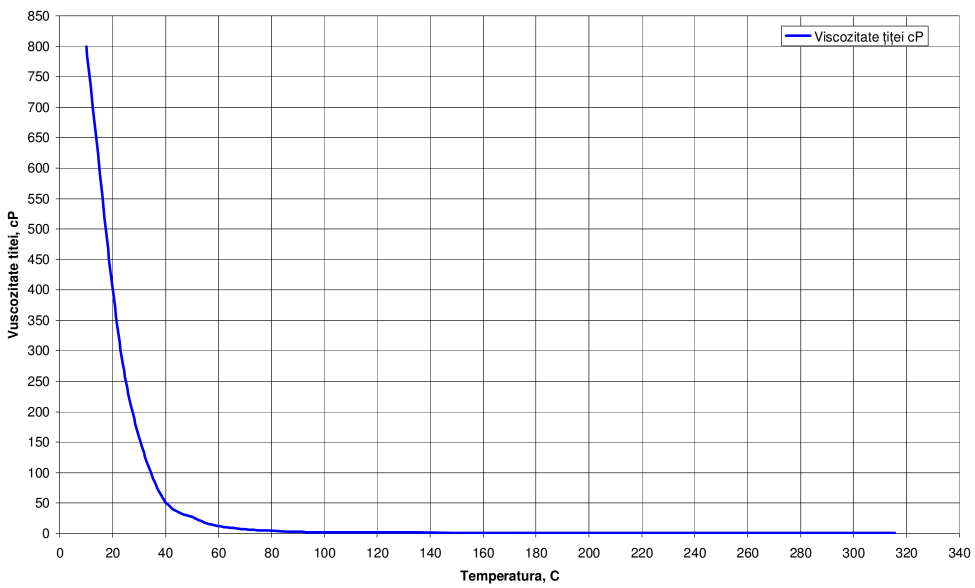

Fig. 1. *Oil Viscosity vs. Temperature*

5. The Simulation Model

The big simulation model has 350 000 cells (100 x 100 x 35) with average dimensions of 27 x 27.5 x 6.5 m.

In order to approach better the temperature's filed distribution, from the initial model was delimited a sector from the crest, with dimensions 100 x 100 x 35. The average dimensions of the cells are: 3.7 x 3.5 x 6.5 m.

Out those 350000 cells only 133000 were considered active, due to high volume of calculation and in order to save CPu time. In figure 4 is presented the sector model and the effective simulation zone.

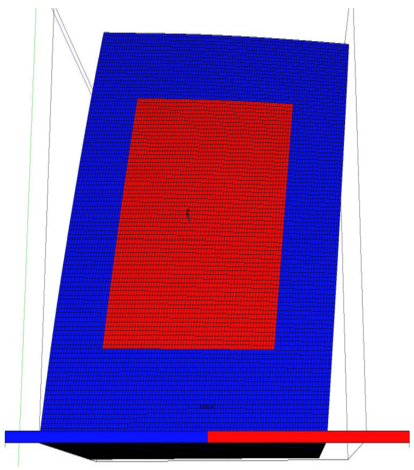

Fig.. 4. *The sector model and active cells (red)*

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One well was considered in the center of the sector model, opening layers 4 to 32 and is scheduled to simulate a cyclic steam injection with the following defining parameters of one cycle:

- inject steam with quality of 65% and with temperature 260 C at flowrate of 160 m^3/day cwe (cold water equivalent) for 35 days;
- well closed for 21 days to allow the heat to be transferred to the rock – fluid system;
- well producing for 56 days at 100 m^3/day fluid.

The main idea is to produce at a balance; meaning that the volume of fluids injected should be slightly equal with the volume of fluids produced in order to avoid any noticeable pressure variation at field level.

There were simulated 7 cycles of injection and the results were reported daily for both injection and shut-in periods, but for the production period were reported weekly.

Due to the low dimensions of the cells and high rates, the timee simulation time steps were small; from 0.05 to 0.85 days and there were encountered may convergence problems.

These convergence problems were finally overcome by reducing the time steps. The total amount of CPU time was nearly 8 hours by using a Dell M90 Precision with 2 Gb of RAM and 2.3 GHz dual core processor.

The next figures are presenting the properties' distributions within the model.

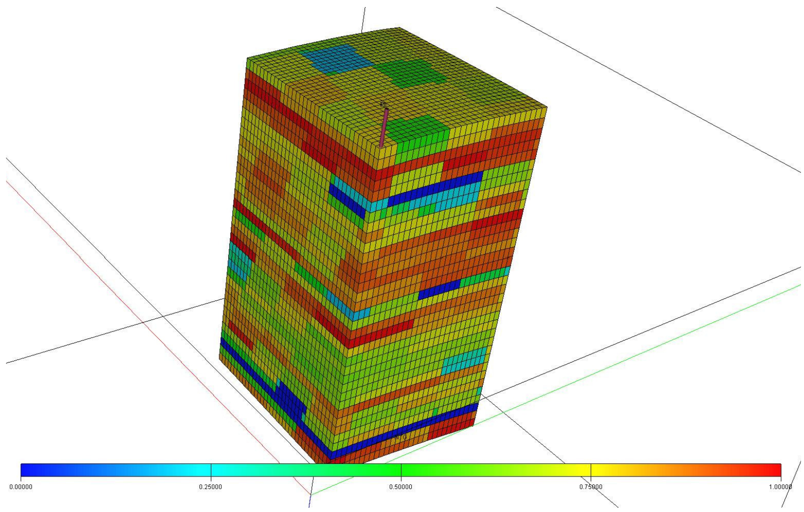

Fig. 5. *The net-to-gross's distribution*

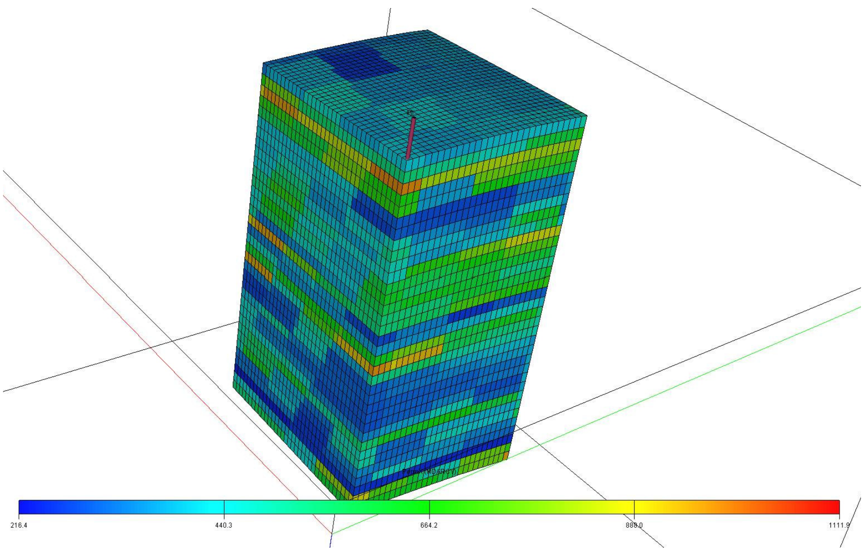

Fig. 6. *The permeability's distribution*

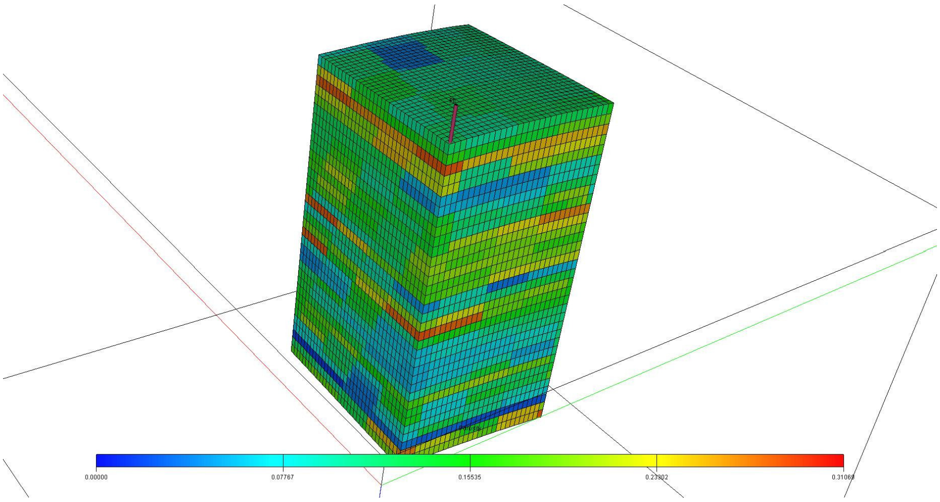

Fig. 7. *The porosity's distribution*

The next figures are presenting the dynamic of temperature's field distribution during the simulation:

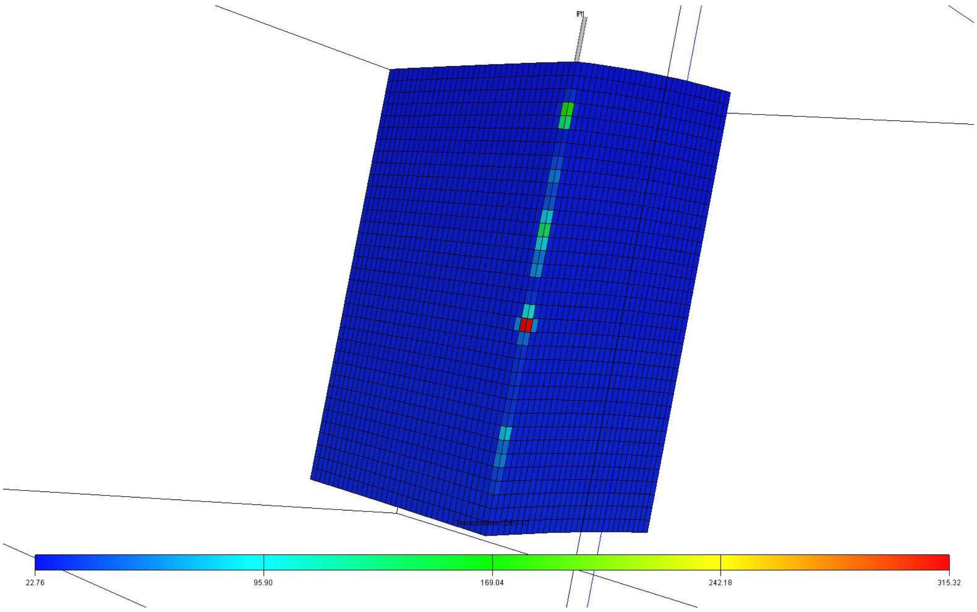

Fig. 8. *Cycle 1 – Distribution of the temperature at the beginning of injection (day 1)*

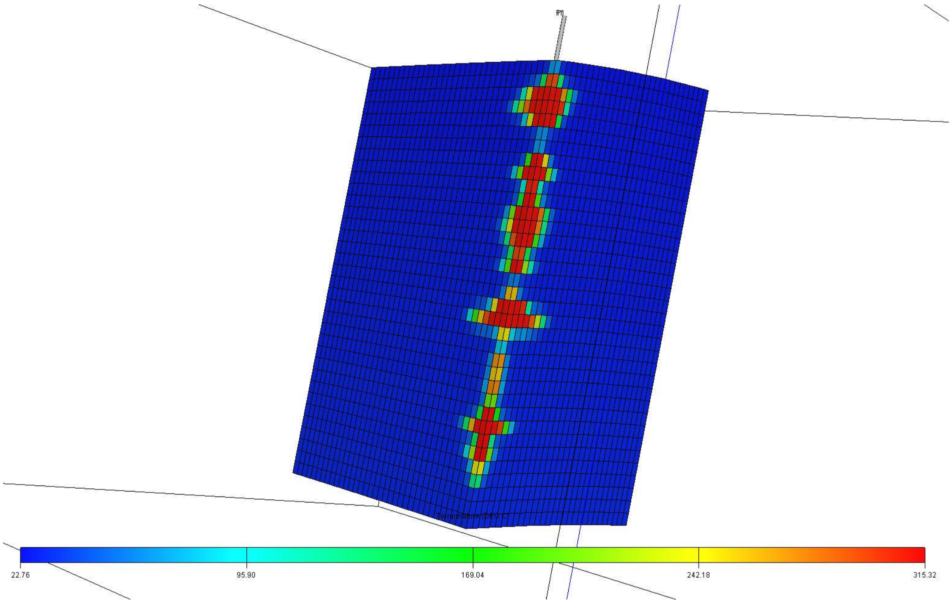

Fig. 9. *Cycle 1 – Distribution of the temperature at the end of injection (day 35)*

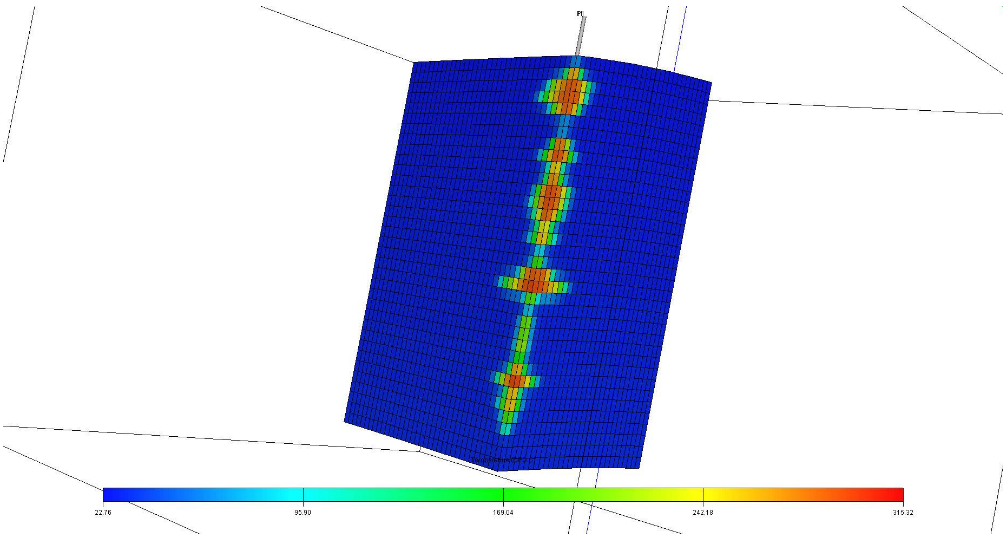

Fig. 10. *Cycle 1 – Distribution of the temperature at the beginning of production (day 56)*

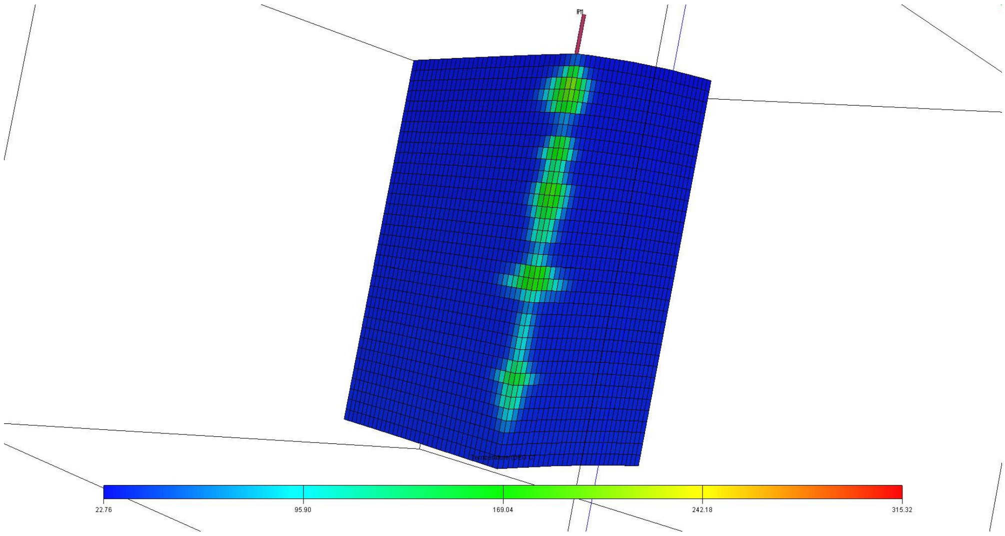

Fig. 11. *Cycle 1 – Distribution of the temperature at the end of production (day 112)*

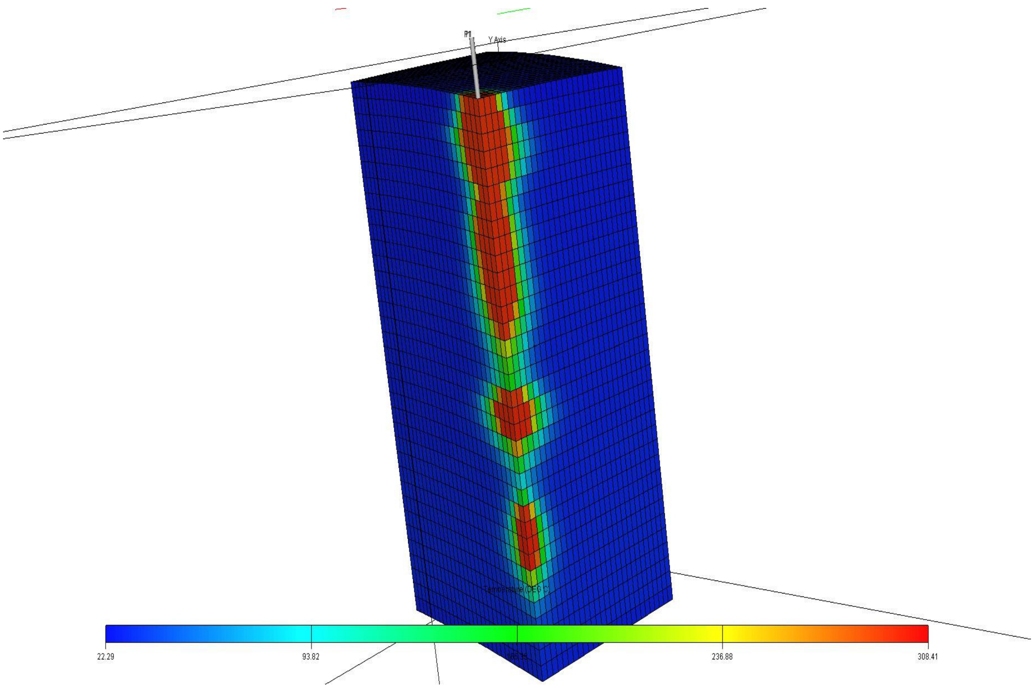

Fig. 12. *Cycle 7 – Distribution of the temperature at the end of injection*

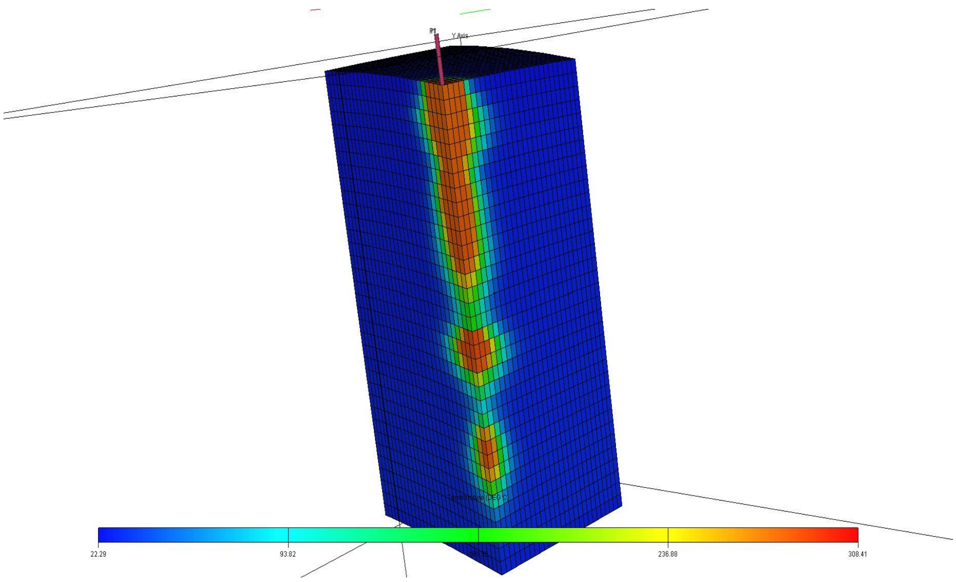

Fig. 13. *Cycle 7 – Distribution of the temperature at the end of heat transfer period*

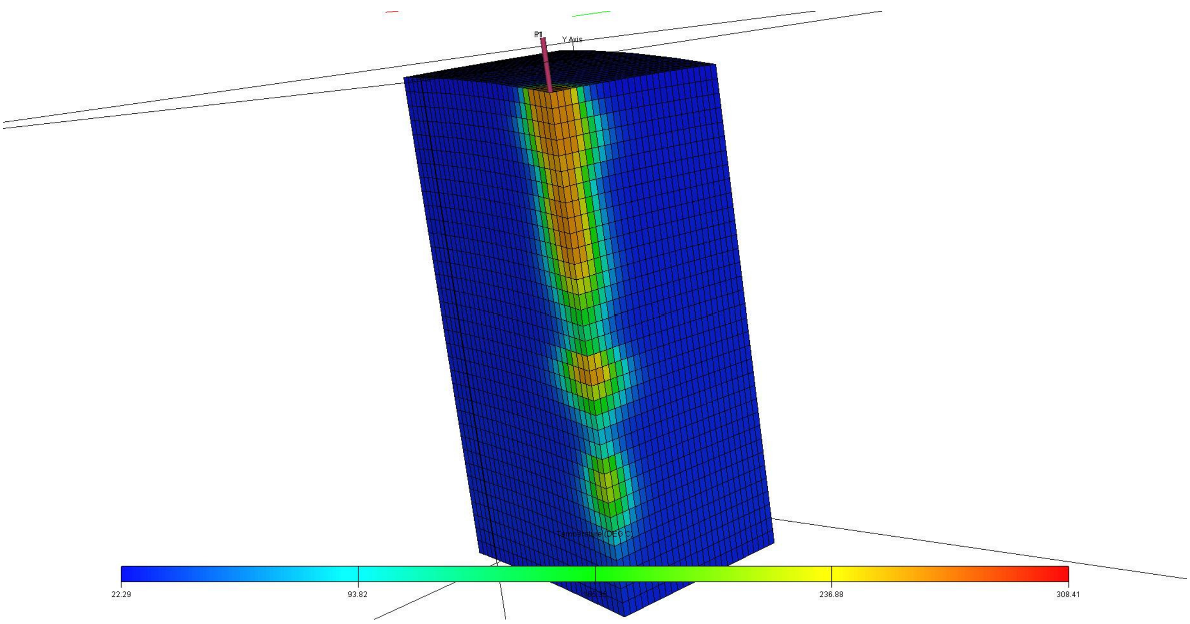

Fig. 14. *Cycle 7 – Distribution of the temperature at the end of production*

6. Conclusions

This paper is intended to show the distribution of the temperatures' field during a simulation of a thermal recovery method (cyclic steam injection) within a heterogeneous porous media. The simulator used is one of the market leading simulator ECLIPSE E500 Thermal™ produced and commercialized by the Schlumberger company.

At the end, we could conclude as is follows:

- The movement of fluids in porous media associated with a variable temperature field occurs in recovery thermal process of the oil from reservoir;
- In the case of the fluids movement with heat transfer there is the temperature as a variable and is used the equation of heat conservation when the sources and chemical reactions are missing, with Darcy's Law and mass conservation equation;
- In this paper is presented a thermal simulation model which determine the distribution of the temperature field around the steam injection wells and show, qualitatively, the phenomenon that are taking place into an oil reservoir;
- It was carried out a geological model and a fluid model too;
- After more injection cycles it was obtained the distribution of temperature field at different stages of process;
- The knowledge of temperature distribution is very important in EOR processes using thermal methods to forecast the behavior of oil reservoir and to increase the recovery factor.

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