Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Geothermal Well Discharging: Short and Long Periods

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Keywords: Well testing, reservoir engineering, modeling, field management

ABSTRACT

For any geothermal development project the more expensive assets are the wells therefore its energy potential assessment will be relevant and valuable data gathered during successive stages of the project. To assess power potential of geothermal wells will require discharge test facilities and the injection availability (pond or wells). This paper analyzed the wellbore behavior for short term period (hour or days) and long term (month or year). The time domain behavior is modeled using TOUGH2 in order to predict the radial effect of pressure and temperature for different permeability measured in some geothermal reservoirs. The results indicate for low permeability reservoir (10 to 50 mD) long term (monthly) discharge could be necessary to reach stable pressure and temperature condition however for high permeability (100 md or more) weekly discharge could be enough to have stable condition. The chemical assess could be require more time to reach stable condition for liquid and gas components

INTRODUCTION

Geothermal wells can generally be divided into two types: those producing a single phase discharge such as the dry or superheated steam, there are some geothermal fields with the entire bore field in that condition, however in several exploited fields there are at least some wells producing only dry steam, and those which deliver two phase or mixtures of liquid and steam.

Geothermal wells are drilled to extract to the surface mass and energy from geothermal reservoir, therefore testing data or discharge information must be required which could include at least: flow rate at several well head pressure condition, mixture enthalpy, fluids chemistry, flowing pressure and temperature, etc. All the data collected are necessary not only to evaluate the performance for power plant potential but are useful for comparison purposes when measurements are taken at time intervals. This may lead to predictions of the field life under exploitation using 3D numerical modeling and to estimates the volumetric capacity of the reservoir.

During the discharge test also can be possible to measure the Non Condensable Gases (NCG) in especial during long term test. The NGC in the steam have large influence on the designed condenser pressure and therefore on the power output efficiency.

The drilling of wells mainly geothermal wells are quite risky and the results are often inconsistent due the complex and poorly known of the nature of the geothermal systems (James 1970). Typically the upper part of a geothermal well are closed off by a series of casing pipes; to stabilize the well, to close off non-geothermal hydrological systems and for safety reason. The deeper part of the well are either fully open or cased with so called liner (slotted linner), which is not cemented in place but perforated in selected intervals, to allow fluid (liquid or steam) to flow from the reservoir into the wellbore. The wells are drilled following a casing program, among several casing program the more popular one is shown in Figure 1.

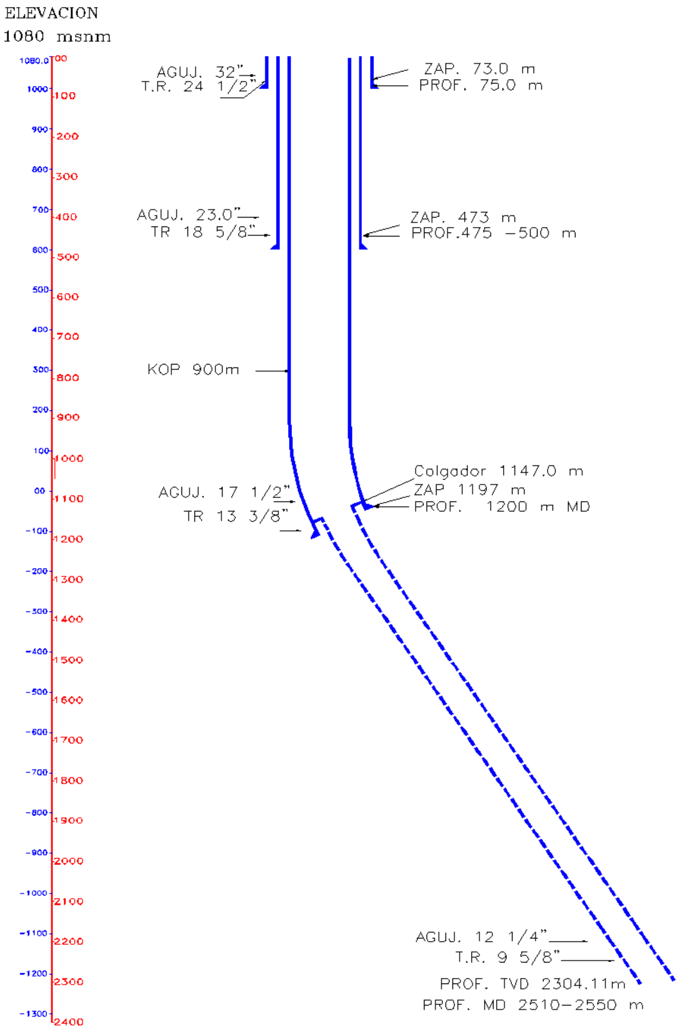

Figure 1: Typical casing program for deviated geothermal wells

WELL PRODUCTIVITY AND DISCHARGE TEST

In general the productivity of geothermal wells is a complex function of (Axellsson 2013):

1- Well bore parameters such as diameter, friction factors, feed zone deep

2- Feed zone temperature and enthalpy

3- Feed zone pressure which depend directly on reservoir pressure and permeability

4- Well head pressure (WHP) or depth to water level during production

5- Temperature condition around the well

Most of these parameters can be assumed approximately constant for reservoirs under production, except for the reservoir pressure, which varies with time and the overall mass extraction from the reservoir. The feed zone temperature and enthalpy may also vary with time in some cases, although usually more slowly than reservoir pressure.

Once the well has been drilled so completion test can be done and warm up period is finished, the site must be prepared for discharge test. After a well has been allowed to warm up sufficiently it is ripe for output testing. In case of high temperature wells this usually involves spontaneous discharge through boiling at depth in the wellbore, which creates the pressure drop necessary to drive the flow of the geothermal fluid from the reservoir, through the well, and to the surface.

Measurement the well discharge of single phase wells is relatively straightforward whereas measuring the discharge mass and energy of a two phase well is much more complex. There are two of four key parameters which could be measured or estimated: liquid flow, steam flow, total mass and enthalpy.

Grant and Bixley, 2011 presents several methods could be used to estimate the output of two phase wells at surface:

1- Liquid and steam phases are separated in a separator (cyclone or webre type) and each phase are measured separately using standard one phase flow meters (ventury, orifice disc, annubar type, etc.).

2- Using vertical discharge and lip pressure method (Russel James) as is show in Figure 2.

3- Using horizontal discharge to the silencer (atmospheric separator) and lip pressure method (Russel James) as is shown in Figure 3.

4- Using two different chemical tracer to measure the flow rate of each of the phase in a pipeline, this method is known as Tracer Flow Tracer (TFT)

The Figure 2 shows the vertical discharge method using lip pressure or Russel James which is very useful in blind field.

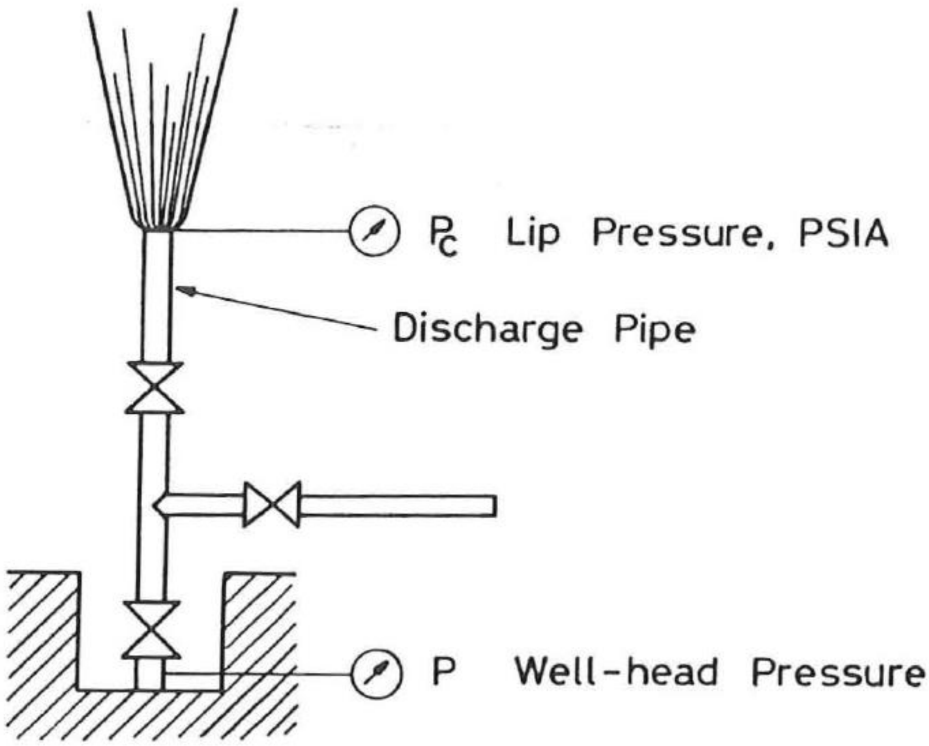

Figure 2: Lip pressure method for geothermal wells

Figure 3: Discharge test facilities in a geothermal well

The Figure 3 shows the standard lip pressure method using silencer and horizontal discharge; these facilities are environmental friendly and involve liquid disposal systems and electronic devices for monitoring.

During discharge test are measured the WHP, Lip pressure into discharge pipe, liquid level in the weir box. If it is possible the measurement device could be electronics connected to data logger.

Additional monitoring could be done among liquid and gas sampling for chemistry analysis, monitoring of quality of air in the pad, wind direction, etc.

To estimate the mass flow rate we can use the following formula

$$\frac{ml(hv-hl)}{(hv-h)} = \frac{1319\,pc^{0.96}D^2}{h^{1.102}}$$

where ml: is liquid flow rate at weir mass (kg/s)

D^2: is discharge pipe (mm)

Pc: lip pressure in bar

h, hv, hl : are mixture, steam and liquid enthalpy (kJ/kg) respectively at atmospheric condition

DISCHARGE DATA AND ANALYSIS

The Figure 4 presents an example of six months discharge test undertaken in some geothermal wells in Central America, during the test James method are been used to estimate the production condition delivered from the well. All the equipment were described previously

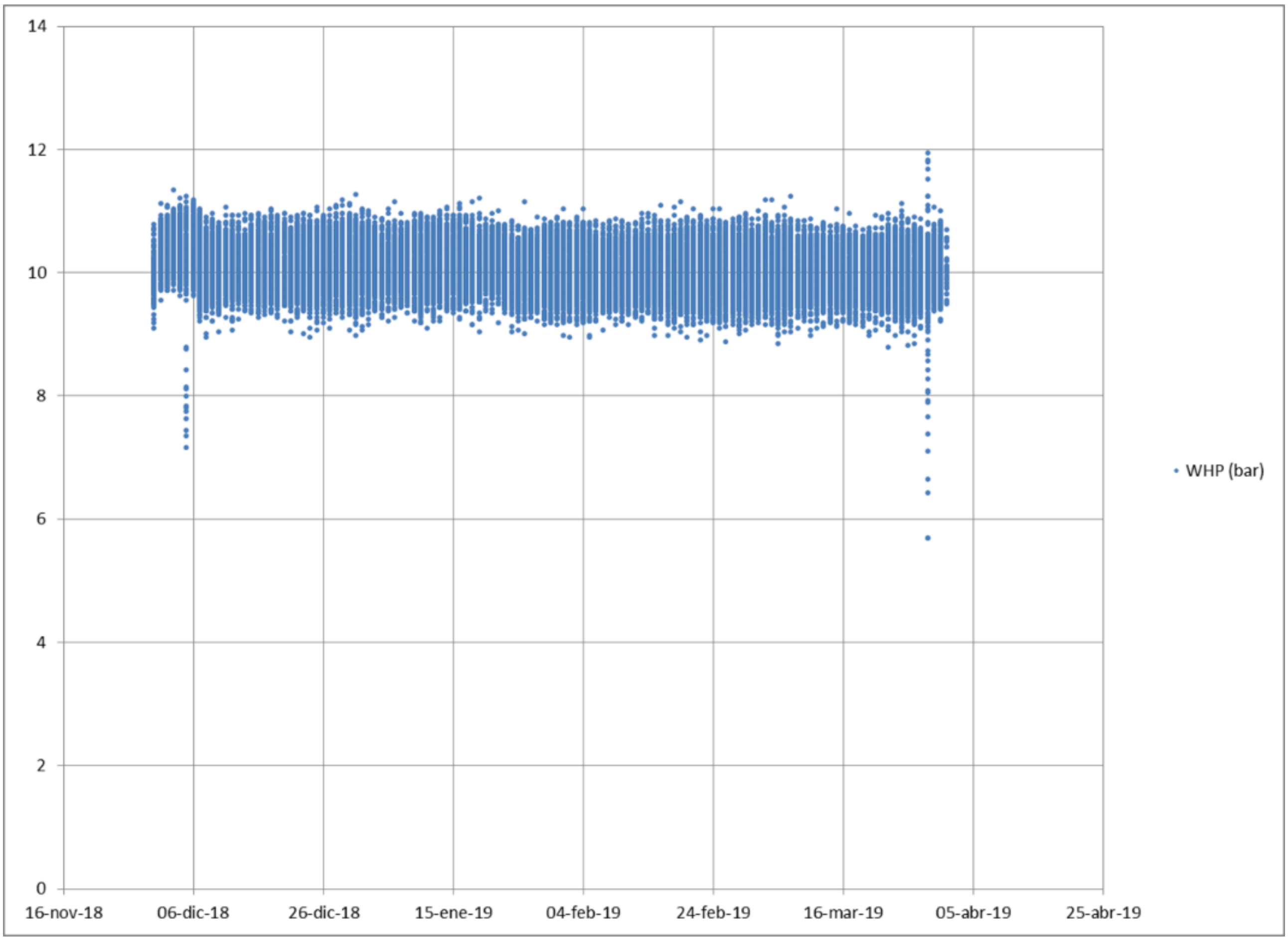

Figure 4: Six months discharge test at geothermal well

At least three stages (moments) regularly are being observed during discharge of the wells:

a. Short term transient condition during the first minutes once the well starting discharge and the flashing move the fluid towards to surface, the storability (S) deliver the fluids and transmisivity (kh/μ) starts to move the fluid from the surrounding areas.

b. Medium term steady state condition, once the fluids is arriving from the surrounding areas the 3D permeability is playing an important role to maintain stable conditions

c. Long term and reservoir effects it is undertaken after steady state has been reached, this effects is large when the interference is observed for several production and injection well are in operation.

To complete the analysis of well discharging a numerical simulation were done to estimate the effects of some parameter in special que permeability of the rocks.

NUMERICAL MODELING

In order to estimate the effects of mass and energy extraction from a geothermal well a 3D numerical model was constructed using a rectangular mesh of 5000 m x 5000 m divided into 30x30 rectangular blocks, each one of 166x166 m. The reservoir consists in two layer of 500m thickness each one to simulate the whole reservoir, the same rocks properties were used for future evaluation of the effects for some changes on this parameter. TOUGH II code (Pruess, 1978) and pre and post processor Petrasim were utilized.

For production purposes a well was located in the center of the volume and the flow rate coming from this element is successively 10, 20, 50 kg/s

Two rocks type with similar value were used with following parameters

Parameter	Value	Units
Rock density	2600	kg/m^3
Permeability x,y,z	100	mD
Rock porosity	10	%
Specific heat	1000	J/kg.°K
Wet heat conductivity	2	W/(m.°K)

The initial conditions for all the elements are temperature 260 °C and pressure 40 bar. The models were running during 1, 7,150 and 365 days, In order to estimate the effects into the model. The Figure 5 presents the numerical grid used in the modeling.

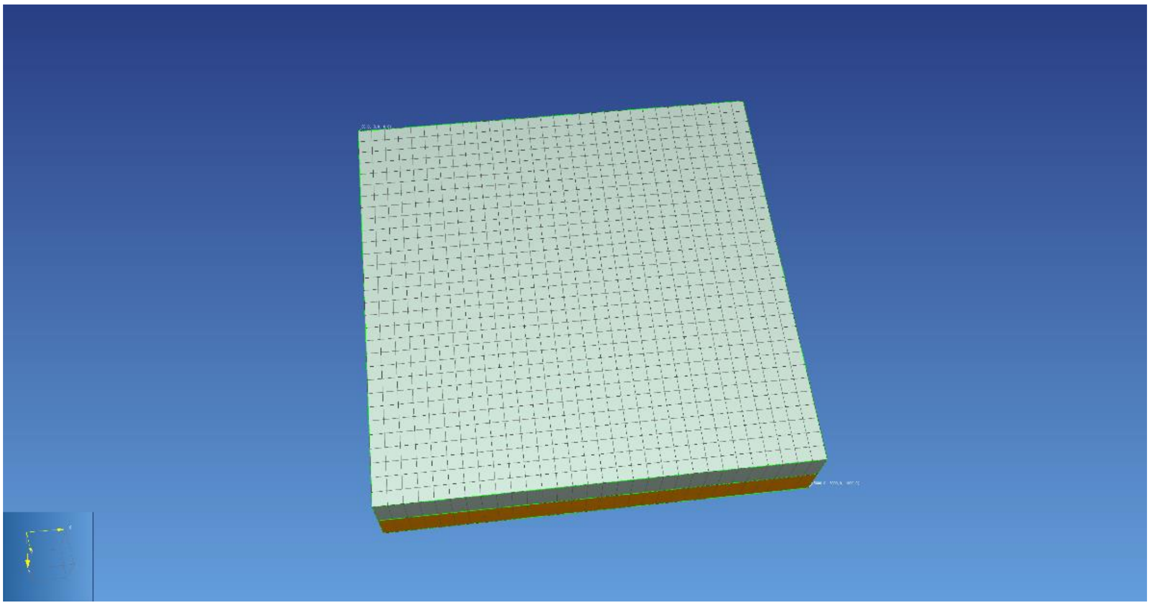

Figure 5: Rectangular mesh used to simulate a well discharge test

MODELING RESULTS

IN order to reduce the printing spaces, it were presented only few of the results. The Figure 6 shows the results for time 1 day, flow rate 10 kg/s and K= 10 mD

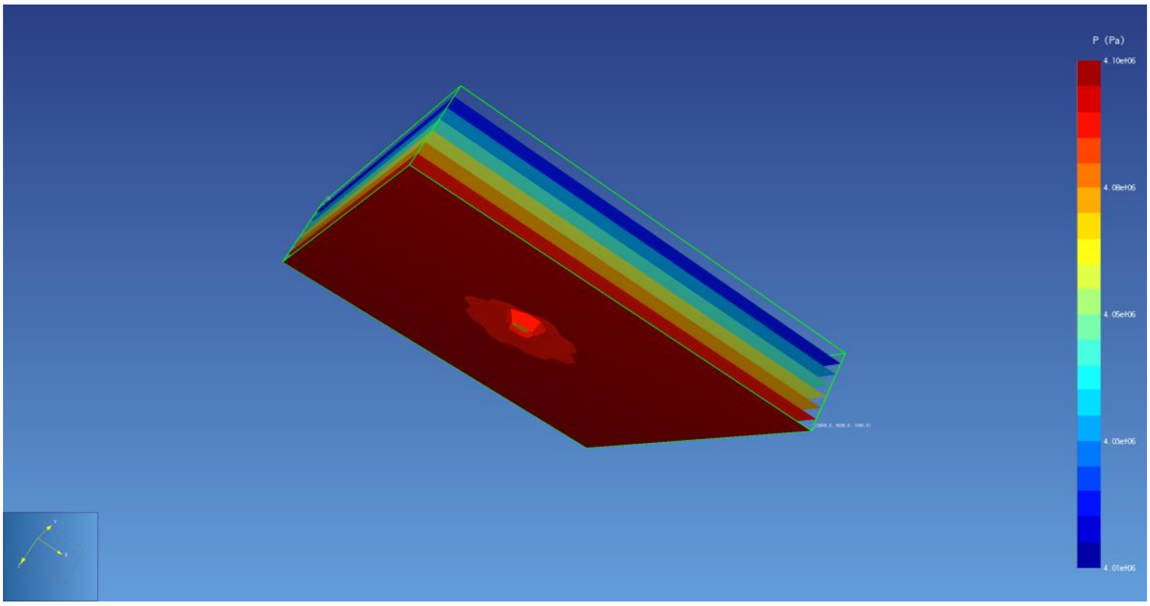

Figure 6: Model results for 1 day extraction

The Figure 7 show the results for time 3 days, flow rate 10 kg/s and K= 10 mD

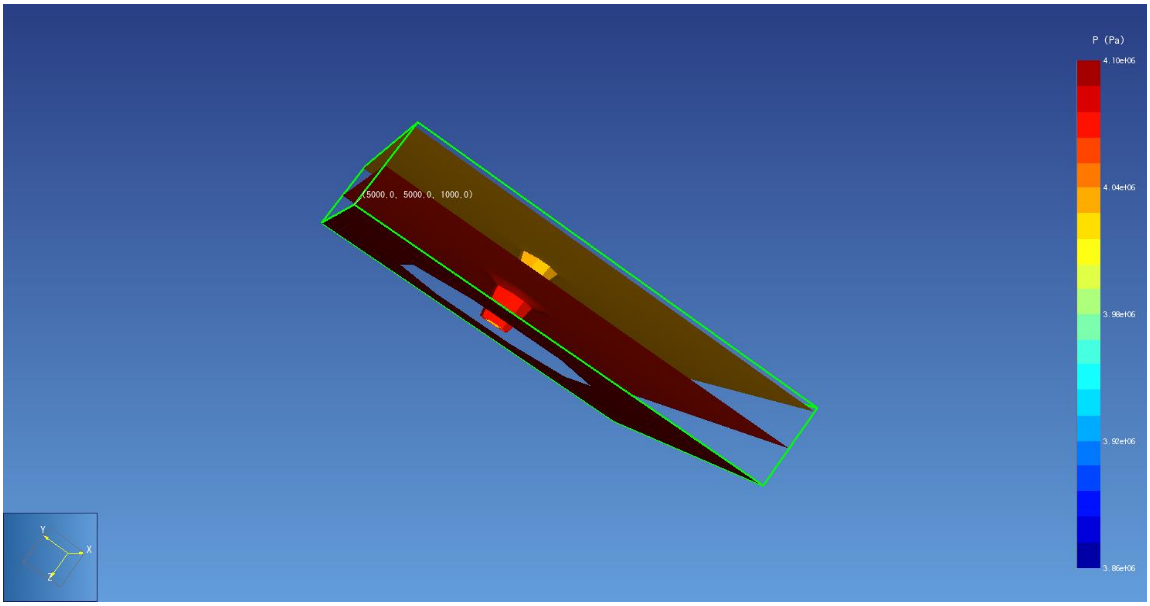

Figure 7: Model results for 3 day of extraction

The Figure 8 shows the model results for time 7 days, flow rate 10 kg/s and K= 10 mD

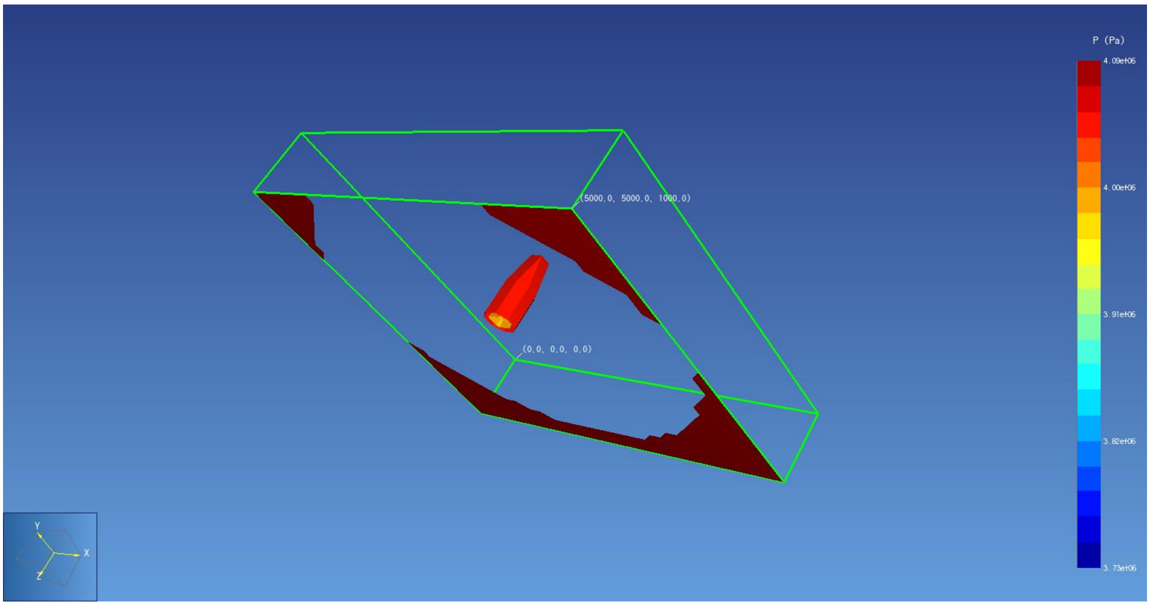

Figure 8: Model results for 7 days of extraction

The Figure 9 shows the results for time 1 day, flow rate 10 kg/s and K= 100 mD

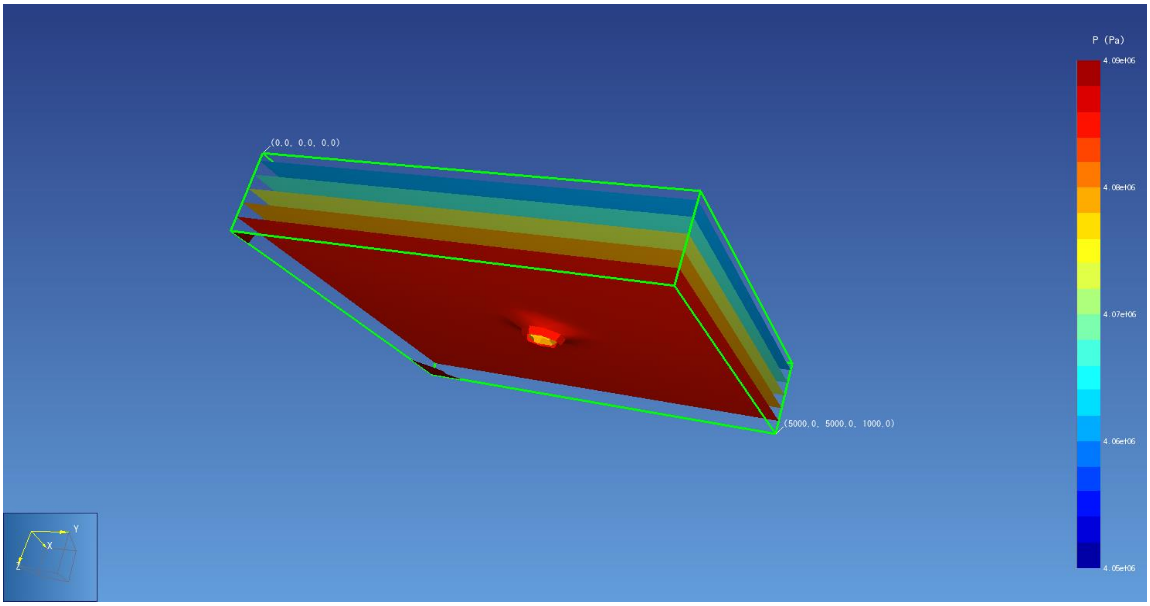

Figure 9: Model results for 100 md and 1 day of extraction

The Figure 10 shows the results for time 3 day, flow rate 10 kg/s and K= 100 mD

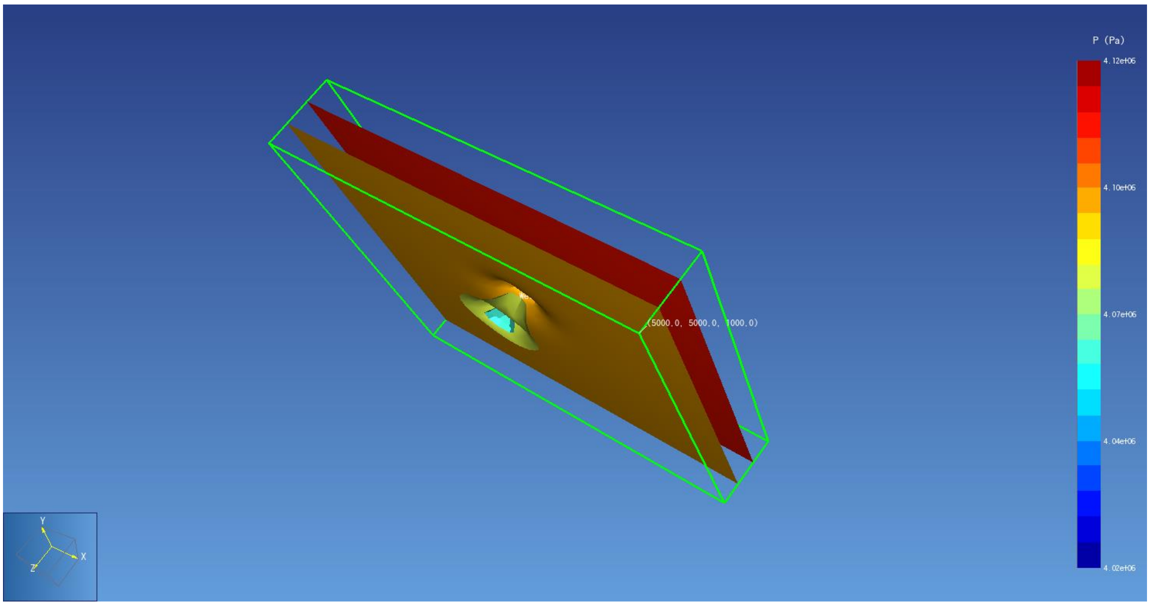

Figure 20: Model results for 100 mD and 3 days of extraction

The Figure 11 shows the results for time 7 day, flow rate 10 kg/s and K= 100 mD

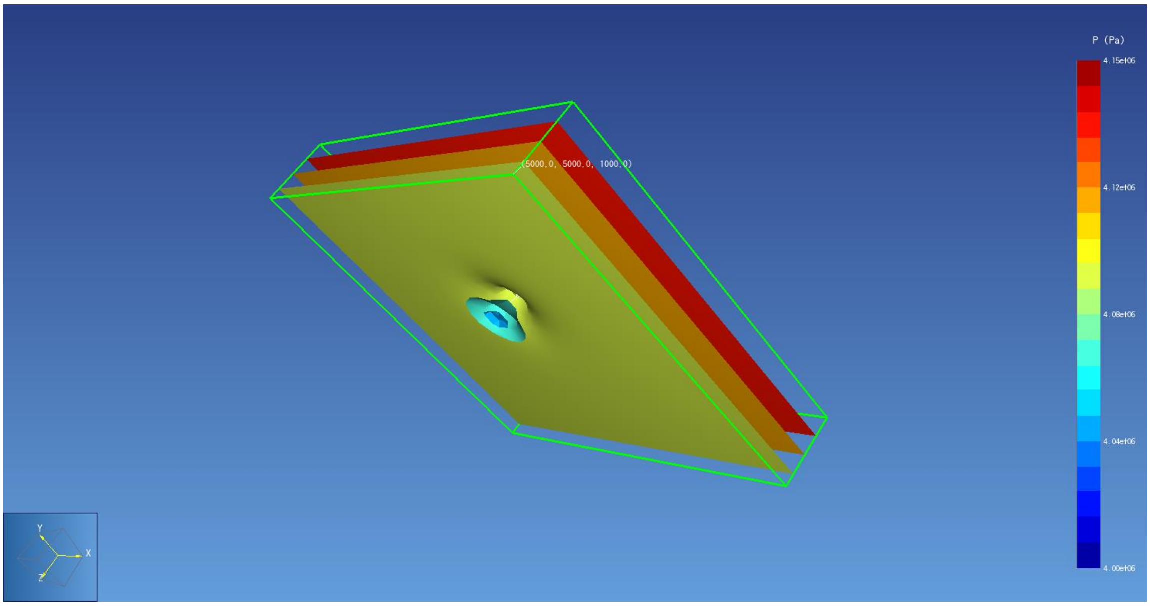

Figure 31: Model results for 100 mD and 7 days of extraction

The Figure 12 shows the results for time 30 days, flow rate 10 kg/s and K= 100 mD

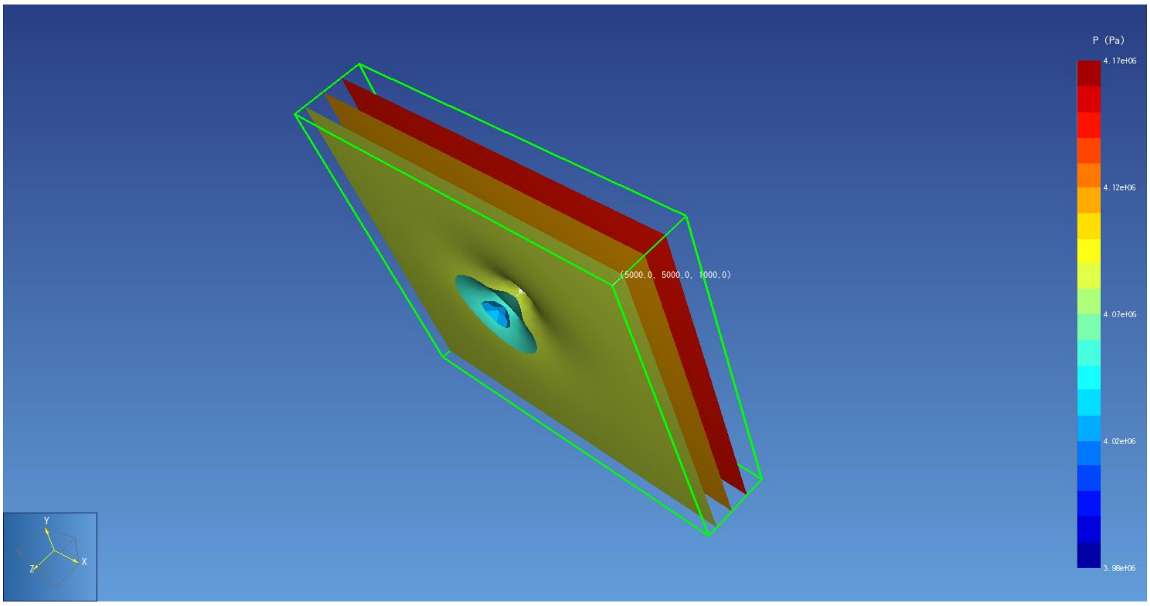

Figure 42: Model results for 100 mD and 30 days of extraction

The Figure 13 shows the model results for time 1 year, flow rate 10 kg/s and K= 100 mD

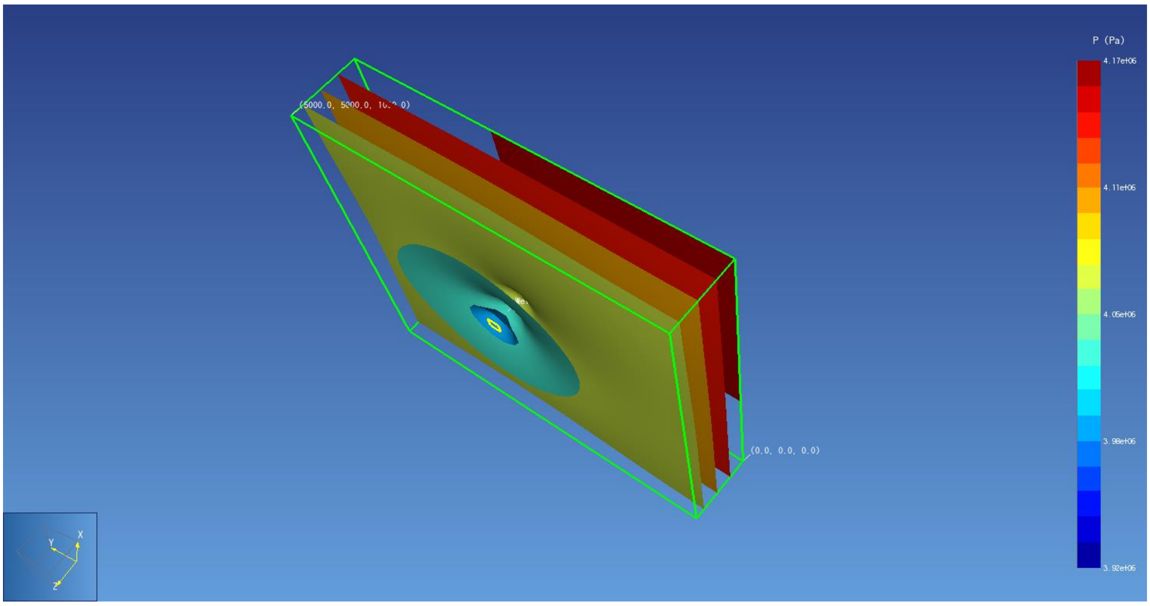

Figure 53: Model results for 100 mD and 1 year of extraction

According with the results a pressure drawdown of 1 – 1.5 bar for a period of a week is expected quite stable for a year extraction, if permeability is 100 md less area or volume could be affected for this extration.

CONCLUSIONS

The discharge of the well it is important data in order to assess the energy potential of any geothermal wells and estimate the mass flow rate delivered from the wells, and to construct the output curve of the well.

The discharge condition of the well will depend on productivity of the wells, reservoir pressure and temperature and well geometry. So the time to reach stable or cuasi stable condition will depend on transmisity/permeability of the wellbore and volume of the reservoir. It is common in geothermal wells to reach stable condition in a few days or weeks however low permeable areas will spend more time to reach the stable condition.

Results from numerical modeling using TOUGHII suggest a volume of the reservoir and permeability distribution around 100 mD will affect quite small part of the system therefore a less time is requiring to reaching stable condition.

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