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A Study on Geothermal Battery Energy Storage

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ABSTRACT

As solar and wind energy have been introduced very well in electric grids but the economical utility in large scale storage has not yet been available to handle the seasonal nature of solar and wind energy, therefore Geothermal battery energy concept can be used as a large -scale renewable energy method., where we can use the solar radiance to heat the water at the surface and then this hot water can be injected into the earth. This injected hot water creates a high temperature reservoir which is acceptable for convectional geothermal electricity production plant, where we can carry this hot geothermal fluid through pipes from deep sub -surface and bought to the earths ground where with the help of various post processing techniques we can use this geothermal energy for heating and cooling purpose or this energy can be harnessed to form/ generate clean electric energy. The unique feature of this geothermal energy storage would be the application of the sedimentary reservoir basin with the formation of high porosity and high permeability with water saturation. The main aim of this concept is to get nearly high efficiency of the stored heat recovered and use this in long term and seasonal storage possible.

1. INTRODUCTION

The method of using hot injected water into the non-movable deep underground which stores that hot heat for longer term and that heated water can be utilized later for electric grid, this method of storing hot water underground is not new, the innovation in this research is the reservoir characteristic and the design of the reservoir which is feasible and economical (Shah et al., 2019). Interest in energy storage has become more evident due to increasing demand of solar and wind energy and other form of renewable energy which are seasonal and due to that the method of storing energy underground and using that energy in offseason has become more important . Solar radiance is used for heating the water at the surface and then this heated water is stored deep inside the earth for later use (Shah et al., 2019).

In many studies, regions of high geothermal gradient were considered, involving high porosity and high permeability with large mass rocks which tend to be heterogenous in nature, however it is not necessary that high geothermal gradient is required we can still carry out energy storage in low porosity and low permeability with less mass rock. In both the cases the water must be fully saturated and there should be low permeability sealing cap lying overhead.

The energy storage is only viable and economical when injected heat is fully recovered and to achieve that proper reservoir is must. Reservoir design depends on many factors and we will discuss that in later sections. Here hot water is injected and then same is produced for use when other form of energy is not available (Sircar et al., 2017; Shah et al., 2019., Shah et al., 2020).

2. HOMOGENEOUS AND ISOTROPIC RESERVOIRS

Temperature and pressure were calculated at different pores at various distance away from the injection well. Various calculation was performed with different parameters like porosity, permeability, reservoir thickness, number of injection water cycle, injection rate, thermal conductivity of water and rock. In all the cases homogenous and low permeability were consider.

The calculation was done of the injected water at 250 °C into the reservoir whose temperature is 120°C, the rate of injection was 40 kg/s. Up to 8 hours the injection was carried out and immediately production was done, followed by thermal equalization for 6 hours and then this process was repeated. The base line was being considered at first injection cycle were temperature of the injection was at 250°C and reservoir was at 120 °Cand the reservoir thickness was 110 m thick with 15 % porosity and 100 millidarcies permeability .Calculation were done for constant pressure boundary condition with boundary at various radial distance ,although the injected water and the production water have same mass but their volume difference was seen because of the change in their density which occur due to temperature variations.

2.1 TEMPERATURE PROFILES

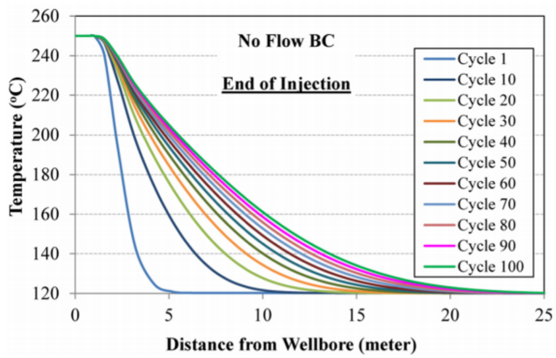

Figure 1 Base line temperature radially from the wellbore

The above figure shows the variation of temperature with the radial distance from the injection bore where water is being poured at 250 °C in the reservoir whose temperature is 120 °C and the rate of flow of water is 40 kg /s and the reservoir characteristic are 110m thick reservoir ,15% porosity and 110millidarcies permeable; temperature increases up to 20 m radial distance from injection bore even when the daily cycles are increased to 100. From this it is analyzed that reservoir permeability has no significant role in temperature variation. Porosity, reservoir thickness, rate of injection and thermal coefficient plays a major role in determining the temperature profile of the reservoir (Figure 1).

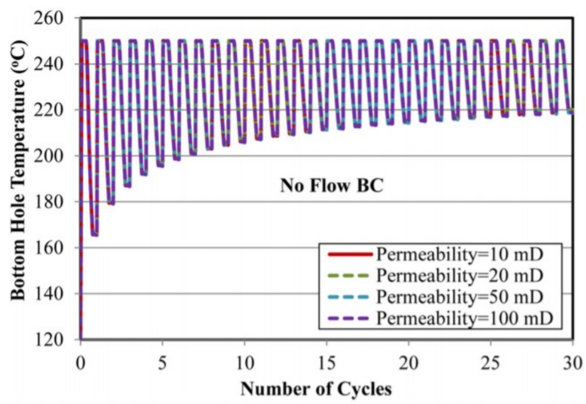

Figure 2 Wellbore temperature for 30 daily cycles

The above figures show the variation in the temperature which occurred during the injection, production and stabilization (Figure 2). The horizontal axis indicates the time in days and the vertical axis depicts the variation of temperature. For injection of water at base line, production temp after about 30 cycles varies from 250°C to 210°C. The temp after 20 cycles indicates that heat loss is small.

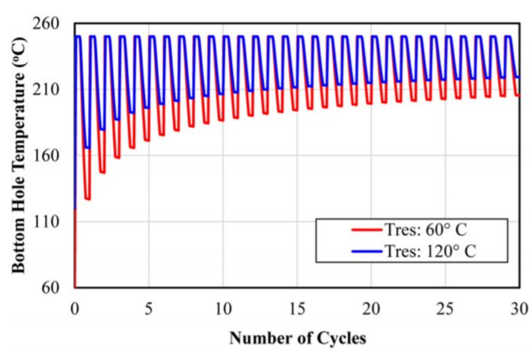

Figure 3 Wellbore temperature cycles for 60°C reservoir initial temperature

In the above figure Horizontal Axis represent the number of cycles and the vertical axis represent the temperature variation, it can be concluded form the above figure that when temperature of the reservoir is decreased and being used as 60°C instead of 120°C then low temperature occurs during injection – production cycles and production – stabilization cycles (Figure 3).

Also, it is being noticed that injection pressure and drawdown pressure also increases during injection and production, both of these are seen due to greater viscosity with low temperature.

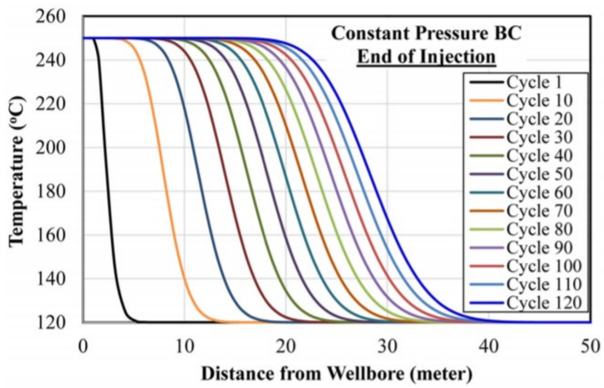

Figure 4 Distance from wellbore

Once the injection is being carried and it is left for much time this is known as charging, for example when the injection was carried out at base line for 8 days then before production starts this left-over period for several days bring the reservoir temperature to injection temperature for about 20 m and elevated reservoir temperature for about 40m. This situation is generally accounted during seasonal change (Figure 4).

2.2 RESERVIOR PORE PRESSURE

For injection of water at high permeability the pressure is always near too constant, and its is also constant during production time. During the equalization time the pressure drops to reservoir pore pressure. Permeability plays a major role on wellbore pressure.

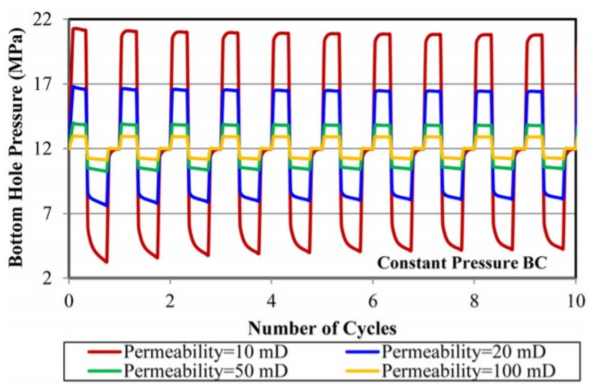

Figure 5 Wellbore pressure for base-line case constant pressure boundary calculation

As shown in the above figure the bottomhole injection pressure increases and production pressure decreases below 50 millidarcies permeability for base line calculation, and wellbore pressure are insensitive to porosity (Figure 5).

As from the above data we have proved that no flow vs radial boundary condition at constant pressure temperature profile does not change, but it has some effect on reservoir pore pressure. as we know that pore pressure changes with the variation in the viscosity of water with temperature and the thermal expansion effects the pore as it gets cooled and heated . For no flow boundaries the pore fluid must get compress and expand within the boundaries (Figure 6).

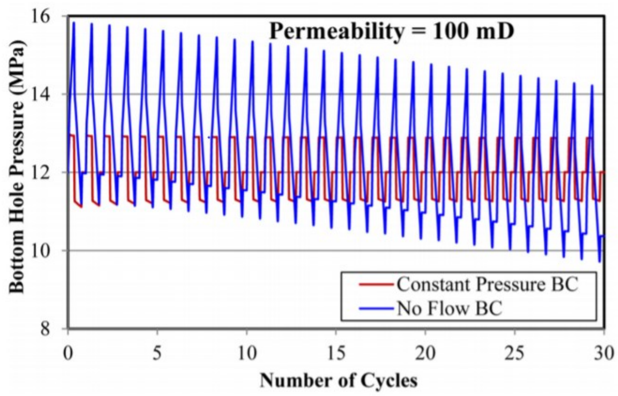

Figure 6 Wellbore pressure for base-line case with different boundary calculations

The above figure shows the variation between bottomhole pressure with injection-production cyces. It can be seen that during injection and production cycles the in situ pore fluid gets expanded and contradict due to temperature gradient ,with that expansion and contradiction can be seen in the rock matrix which indirectly affects the porosity . To determine the change in the porosity with thermal expansion first we need to know the stress which is their in the in situ pores , with low compressibility of water the pressure effects can be seen at larger distance from the well .

3 NON-ISOTROIC PERMEABILITY RESERVOIRS

Effective study was performed in anisotropic reservoir, same base line and constant- pressure was consider in injection and production reservoir. Vertical permeability is not a big factor while calculation injection and production along the reservoir vertical height, for such cases cycle occurs at radial flow. The case of partial penetration or partial completion the calculation is either axisymmetric vertical and radial flow or 3d flow where cycle occurs at only part of vertical well reservoir height (Figure 7).

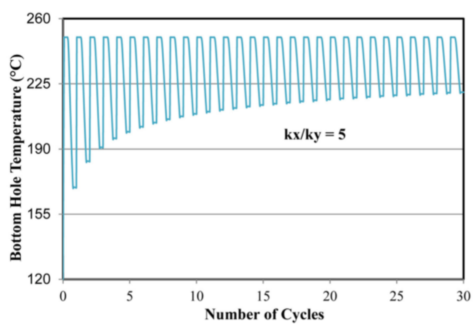

Figure 7 Wellbore temperature for 30 cycles

The above figure shows the wellbore temperature of a cycle over 30 days for a base line case except for variation in horizontal permeability. Horizontal permeability in the x direction is 100 millidarcies and in y horizontal direction is 20 millidarcies. This figure can be viewed with the isotropic horizontal permeabilities, temperature can be found similar .This concept of horizontal temperature is being done by horizontal anisotropy (Figure 8).

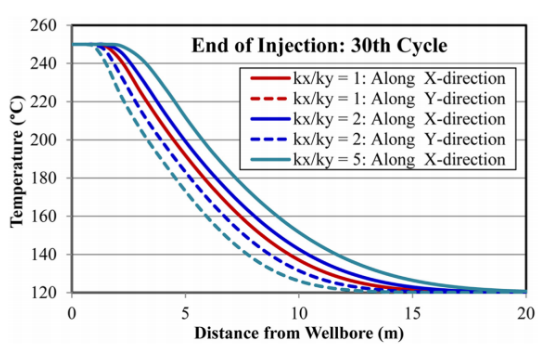

Figure 8 Temperature at distance from the wellbore

The above figure shows the temperature profile of the figure in 9.

It can be seen form the above graphs that 5 m from the injection unit there is 50 °C difference between x and y axis horizontal permeability.

4. LAYOUT OF INJECTION PRODUCTION RESERVIOR

The main objective behind geothermal battery is to stock up hot water in the reservoir and later recover fully or partial this hot water for electric grid purpose. The main factor which accounts in this is the reservoir layout and parameters.

One of the feasible GB is to make Units, each having reservoir in itself. Consider one unit with 9 wells, 8 small diameter hole and one is big diameter hole for hot water production only. Out of 8 small diameters well 4 of them are for hot water and 4 of them are for cold water. The small diameter well of hot reservoir can only inject hot water and is located near to hot reservoir, while the other 4 small diameter of cold water can inject and produce cold water these wells are located near to reservoir where it is left unheated. The big well is used for hot water production, the pressure inside the well is always maintained to prevent scaling and exposure to outside world.

With the help of the above reservoir layout we can perform,

1 when solar energy is available we can use this layout simultaneously by producing cold water from the small cold well and heating it by solar radiance and at the same time we can inject hot water into separate hot well .

2 Using the large well as a production of hot water for electric grid and later reinject that into cold water well.

5. CHALLENGES AND FUTURE SCOPE

The future scope of geothermal battery energy storage is to fulfill the energy demand over the entire period of time by injecting hot water into the reservoir and then production of this hot water later whenever required when solar energy is unavailable. This technology is generally used when the renewable energy exists for limited time and to acquire the demand for energy over period of time this storage technology can be used, one of the main factors which is being kept in mind while featuring this technology is the capability of getting hot production water and hence reservoir designs play a major role, otherwise this method can be very well executed. Except from the reservoir design the surrounding and location climate also plays a major circumstance, at some places it is merely impossible to develop this method efficiently because of the earths underground heat. Hence if we can fully develop reservoir such that we can completely absorbs 100 percent efficiency in recovering of the heated water we can ease the demand of electricity.

6. CONCLUSION

The geothermal energy storage uses underground earth as a storage container for heat water. This type of process is being used since years, what's different in this technique is the use of low volume of high porosity and high permeability rocks which are distant from the complex layering, fractures and faulting. Heated water is poured from the surface to the reservoir and is produced again at the surface whenever needed. Since the high porosity rock carry much porous in its rock, small volume of high porosity rock can carry much of the stored heat in it. As geothermal battery storage depends on certain parameters of the reservoir, so proper knowledge of it is much required and hence we have discussed some of the parameters in this paper. With the increase in the energy we can notice that season energy has rapidly increased which points the major electric production rather than consumption in the particular season, so we can use this excess energy in heating water and storing that in the reservoir for later use. In the above discussion we have discussed the two different types of reservoir mainly Homogenous and isotropic reservoir and the Non-isotropic permeability reservoir and their different parameter analysis.

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