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Geothermal energy extraction from abandoned wells

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Abstract

Below the surface of the earth, there exist geothermal resources with the potential to make a significant contribution to the global demand for energy in an environmental friendly way. Seemingly an endless resource, it could be capable of replacing other sources of energy if treated wisely. A main challenge with the industry is related to the capital expensive costs of drilling the geothermal wells, hence the introduction of abandoned petroleum wells is of interest. In this paper, we seek to investigate the potential amounts of heat extracted from beneath the surface, by retrofitting a double pipe heat exchanger in an abandoned petroleum well. The working fluid of choice is proposed to be circulated down through the annulus, then up through an inner, insulated geostirring. By making use of a numerical simulator, we assess parameters of interest and obtain knowledge on how they affect the outlet temperature of the circulating working fluids and the accumulated heat extracted from the geothermal wells.

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1. Introduction

The world's demand for energy is bound to increase. In order to supply the growing population with the required comfort, environmental friendly and renewable initiatives should be considered above non-renewable energy sources. The CO₂ content in the atmosphere is set to rise, hence the power generation capacity installed from renewable resources should continue to represent the majority of additions [1]. An energy source well worth considering in a process towards a more sustainable and renewable energy production is geothermal, which depends on heat extraction from the subsurface. Geothermal heat has enormous energy potential, hence reliable and steady output is usually expected. The earth's capability to replace the lost heat makes the resource renewable.

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Three types of power plants are recognized in commercial geothermal electricity production, making use of steam turbines and generators. Dry Steam-power plants operate high enthalpy resources, where the temperature is sufficient to vaporize the extracted fluid. A flash-steam power plant vaporizes extracted fluid in a flash-tank, before directing it through the turbine. For the low-enthalpy resources, a Binary cycle power plant circulates a secondary fluid with low boiling point in a closed loop, which vaporizes after heat-exchanging with the extracted fluid. The potential for utilizing a binary-cycle design today is high, as the low- to intermediate enthalpy resources are most abundant. The possibility of utilizing geothermal for heating purposes is an alternative exploitation. Hot fluid recovered from the ground can be piped several kilometers to supply buildings with required heating. Other alternative application areas for the geothermal heat is de-icing of roads, agricultural drying, heating for greenhouses, dry out fish and crops, etc. The novel idea we investigate in this paper, makes use of abandoned petroleum wells for geothermal purposes. With the drilling process already accomplished, the geothermal project can potentially shrink its costs with 50% [2]. When retrofitting an already designed wellbore, the casings and depth are set. By using a modified model and a developed simulator, an investigation of a double pipe heat exchanger retrofitted to an abandoned petroleum well, is carried out. By heat-exchanging, the circulating working fluid will gather heat-energy going downwards then, bring it up through an insulated geostirring. The presented heat transfer model takes many parameters into consideration, like formation properties, working fluid properties, wellbore architecture, etc. The sensitivity analysis carried out by the simulator provides valuable knowledge on construction design, fluid properties, geological conditions, etc. which affects the extracted heat and temperature.

2. Properties of working fluids

2.1. Specific heat capacity C_p , thermal conductivity k and Viscosity μ

The specific heat capacity is defined as measurable physical quantity, related to the ratio of heat removed from or added to a system, to the resulting temperature change. It is difficult to estimate or predict for different temperatures. The thermal conductivity is a materials ability to conduct heat. Higher values of k implies better heat conduction across a material, hence these materials are often used for heatsink- and heat exchanger purposes. The thermal conductivity of a material may vary with temperature and convection. In the case of high temperatures in fluids, convection is often present and this results in an increase in thermal conductivity. The thermal conductivity in a geothermal well influences the conduction of heat in radial direction. Dynamic viscosity is a fluid property of interest, as we examine heat transfer mechanisms in the geothermal well. It is a fluid property of great importance to several industries, but here it will have an impact on the heat transfer mechanisms taking place in the circulation process. [3].

2.2. Nusselt number, Prandtl number and Reynolds number

This equation introduces a correlation between the convective heat transfer coefficient and the Nusselt number. It is commonly defined as the ratio between occurring convection and conduction across a boundary [4, p. 787]:

$$Nu = \frac{hD}{k} \quad (1)$$

where h is the convective heat transfer coefficient, D is the equivalent diameter of the pipe considered. Prandtl number approximates a number for the ratio of momentum diffusivity to thermal diffusivity [5]:

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