THERMAL LIFT EFFECT IN GEOTHERMAL WELLS – USE OF PYTHON LANGUAGE TO AUTOMATE CALCULATIONS

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Introduction

The interpretation of well tests or long-term observations of wellhead parameters is an extremely valuable tool in the correct assessment of geothermal resources. Despite using the same relationships describing the hydraulics of geothermal water flow as in the case of freshwater or oil, an important factor that introduces a certain correction to the interpretation of the obtained results is the influence of temperature on water density. Large fluctuations in water or brine temperature while pumping the well significantly disturb the readings of recorded data - the level of the dynamic water level or the wellhead pressure. Often, due to the lack of the expected shapes of the drawdown curves or the buildup of the water table, the correct interpretation of hydrodynamic tests is impossible. It is then necessary to use only a fraction of the data that is of appropriate quality, which unfortunately may cause lower reliability of the hydraulic transmissivity obtained as a result of the calculations.

Aim of the study

The solution to most of the problems mentioned in the Introduction is to apply the correction for the thermal lift effect, thanks to which the use of classical fluid dynamics equations from the petroleum industry / hydrogeology is fully justified. This abstract presents a tool developed in the Python programming language called THERMALIFT CALC, which automates calculations and generates appropriately filtered data and graphs that can be used for further interpretation. As a result, a dynamic water level or wellhead pressure is obtained that allows correct estimation of the hydraulic transmissivity of the geothermal reservoir. The THERMALIFT CALC was developed as part of the project "*Optimal management of low-temperature geothermal reservoirs – Polish-Icelandic cooperation on reservoir modeling*", acronym GeoModel.

Materials and methods

The thermal lift effect in a geothermal well is a known phenomenon (Kawecki 1995, Bielec and Miecznik 2012, Miecznik 2017), although unfortunately quite often neglected. Due to the thermal expansion of water with increasing temperature, a higher water table level or a higher wellhead pressure value is observed than if this effect is not occurring. There is therefore a smaller drawdown compared to a situation where this effect does not occur, but freshwater equations are still used to interpret the hydrodynamic tests. As a result of interpreting such distorted measurements, the hydraulic transmissivity of the reservoir is estimated to be higher than it actually is. In extreme cases, this may lead to excessive exploitation of resources, especially a significant drop of reservoir pressure.

Figure 1 shows the temperature profile in the well in static conditions and during pumping. Under static conditions, the temperature profile in the well is the same as the temperature distribution in the rock mass. This means that the water column in a non-operated well may be characterized by a large variability in density. During pumping, well is gradually heated. The temperature at the wellhead is closer to the bottomhole temperature the longer the production takes or the higher the flow rate of the produced fluid. The difference in the density of the water column in the pumped well is therefore usually very small.

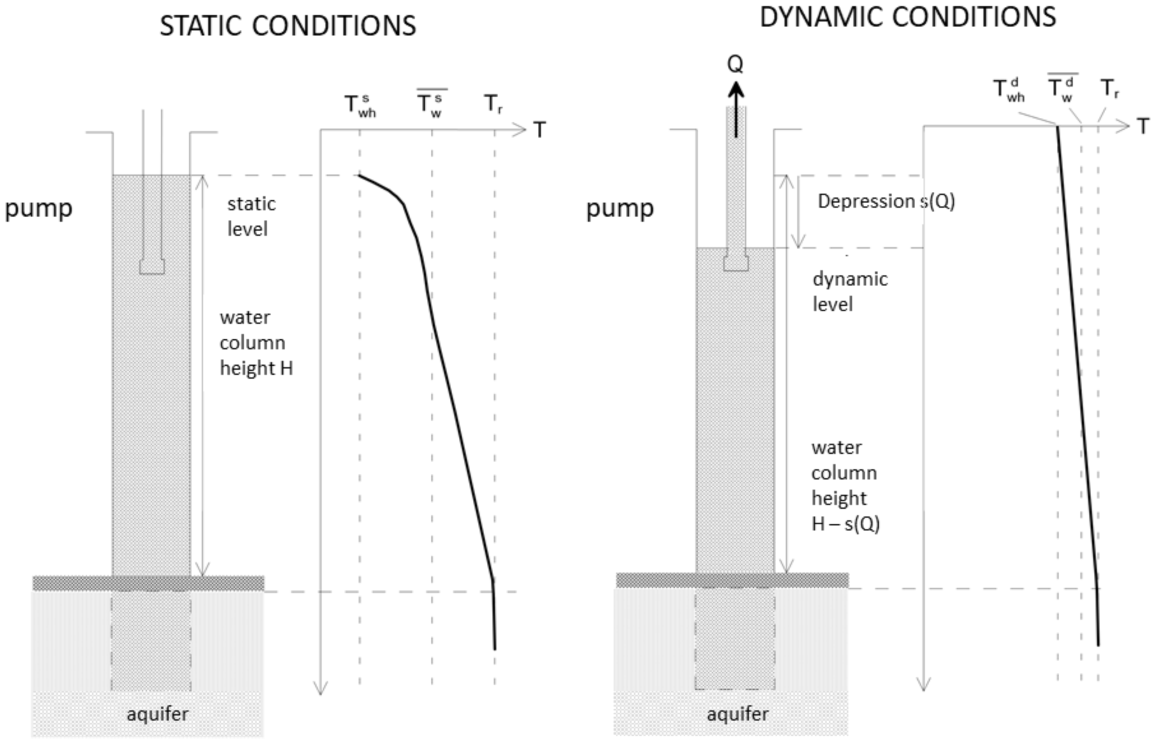

Fig. 1. *Diagram showing the temperature profile in the well under static and dynamic conditions (Miecznik 2017)*

Derivation of mathematical relationships leading to the equation for the so-called reduced wellhead pressure was presented in the referenced literature. Its final form is as follows:

$$p_{wh}^{red} = p_{wh,0} - s\left(\overline{T_w^s}\right)\cdot\rho_w\left(\overline{T_w^s}\right)\cdot g = p_{wh} - \left[1-\frac{\rho_w\left(\overline{T_w^d}\right)}{\rho_w\left(\overline{T_w^s}\right)}\right]\cdot\rho_w\left(\overline{T_w^s}\right)\cdot L\cdot g$$

where:

$p_{wh,0}$ – wellhead pressure under static conditions (non-flowing well)
p_{wh} – wellhead pressure under dynamic conditions (flowing well)
$s\left(\overline{T_w^s}\right)$ – drawdown in the well, i.e. the difference between the water table level in static and dynamic conditions
$\rho_w\left(\overline{T_w^s}\right)$ – water density for average water temperature in static conditions
$\rho_w\left(\overline{T_w^d}\right)$ – water density for average water temperature in dynamic conditions
L – length of the well
g – gravitational acceleration

Therefore, the actual water table level drawdown, excluding the influence of the thermal lift effect, knowing only the static and dynamic wellhead pressure and the estimated average temperature of the water column in static and dynamic conditions, is (expressed in meters of water column):

$$s\left(\overline{T_w^s}\right) = \frac{p_{wh,0}-p_{wh}}{\rho_w\left(\overline{T_w^s}\right)g} + \left[1-\frac{\rho_w\left(\overline{T_w^d}\right)}{\rho_w\left(\overline{T_w^s}\right)}\right]\cdot L$$

As can be noticed, the effect of thermal lift is the more important, the deeper the well is and the greater the temperature difference recorded at the bottom and at the wellhead. For such wells, it is particularly important to correct the pumping results due to the thermal lift effect.

In order to automate such calculations, the THERMALIFT CALC was developed, which allows the calculation of both the actual value of water drawdown in the well and the reduced wellhead pressure. The