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Comparison between discharge enthalpy and dynamic measured enthalpy for pure water in geothermal fields in El Salvador

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ABSTRACT

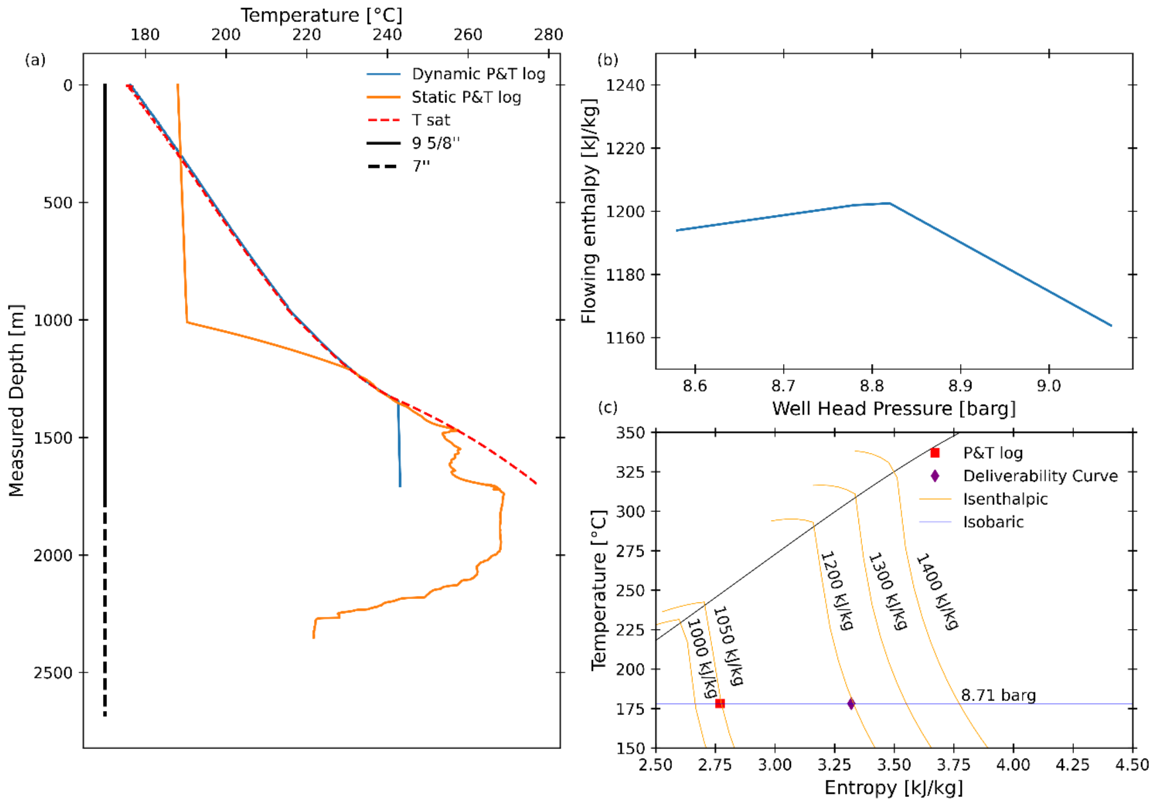
By analyzing a pressure-temperature log from a discharging geothermal well, the flowing enthalpy can be estimated based on the flash point. This method utilizes the pressure and temperature data to calculate the corresponding enthalpy using steam tables. However, in some cases, this hypothesis may not align with the actual flowing enthalpy determined using the calculated lip-pressure method. This discrepancy arises because some shallower and saturated feed zones can contribute to the total flowing enthalpy estimated at wellhead conditions. This study compares the flowing enthalpy from various wells in the Salvadoran geothermal fields using both the measured flowing enthalpy and the lip-pressure method.

Introduction

When assessing the energy potential of a geothermal well in a liquid-dominated reservoir, two primary methods emerge: the separator method and the lip-pressure method [1]. The separator method involves measuring the mass flow rate from both the liquid and gas phases using various devices. In contrast, the lip-pressure method estimates the total mass flow by measuring the wellhead pressure and the lip pressure, which is measured 1/4 inch before the end of the discharging fluid pipe. The Russell James equation is then used to calculate the enthalpy based on these measurements [2]. While the separator method can yield accurate measurements if no steam is carried out on the brine side and calibrated measuring devices are used, it is more costly and logistically challenging compared to the lip-pressure method. The lip-pressure method involves delivering the two-phase geothermal fluid to an atmospheric separator, where it is directed into a series of baffles or vanes to separate the brine from the vertical steam plume. Since the geothermal reservoirs under production or feasibility stage in El Salvador are predominantly water-dominanted, the lip-pressure method has been widely adopted as a production assessment method. However, there is a slight tendency in some wells to overestimate the flowing enthalpy using this method in current facilities. The approach explored in this paper uses the pressure and temperature logs while the well is discharging to estimate the flowing enthalpy at the flash point. However, it is important to note that this method does not provide mass flow rate estimates.

Figure 1c illustrates the discrepancy between the discharging enthalpy estimated using the lip-pressure method and the dynamic measured enthalpy using the PT log for well TR-17. The lip-pressure method estimates enthalpy around 1200 kJ/kg at wellhead conditions (from Figure 1b) and the dynamic measured enthalpy estimates 1050 kJ/kg at the flash point conditions, as indicated in Figure 1a. Considering the well's steam content of 0.16%w, the enthalpy correction is minimal, approximately 2 kJ/kg. Therefore, there is a need to compare these estimated values to obtain a precise indicator that can help with the individual diagnosis of each well and the general processes occurring within specific areas of the geothermal reservoir.

Figure 1. (a) Dynamic and static P&T log and saturated temperature, (b) Flowing enthalpy from deliverability curve and (c) Water T-s diagram with Isenthalpic and Isobaric lines from well TR-17A.



Methodology

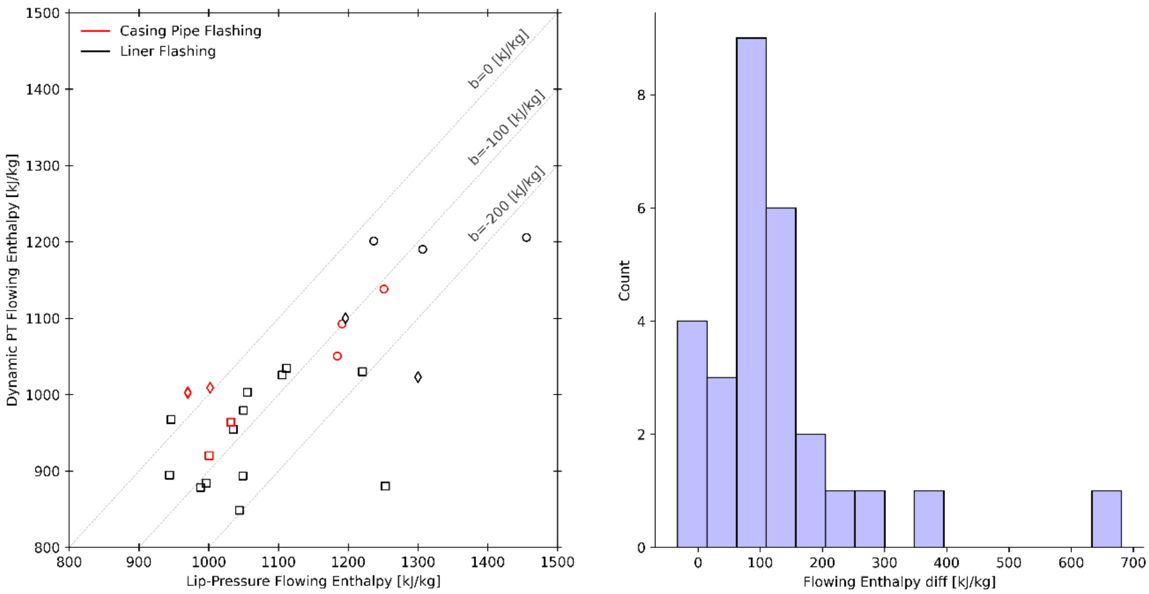
The main steps involve comparing the flowing enthalpy estimated from pressure and temperature logs at the flash point with enthalpy estimated at surface conditions using the lip-pressure method approach. However, not all wells have a dynamic water level inside the wellbore, so a filtering process is necessary to exclude wells with fully saturated conditions.

Next, the wells are categorized into two groups: the first set of data includes wells with the flash point within the production casing, while the second group includes wells with the flash point below the casing shoe. This division is based on the possibility of saturated feedzones above the flash point, which could significantly increase the overall flowing enthalpy. In contrast, if the flashing occurs inside the production casing pipe, the correlation between the methods is expected to be closer to linear.

Results

Figure 2 compares data from 28 wells with identified dynamic water levels and their corresponding wellhead conditions at the deliverability curve. The first dataset shows a closer correlation between each method, with the flowing enthalpy ranging between 0 to 100 kJ/kg. In contrast, the majority of wells in the second dataset exhibit a difference between 50 and 200 kJ/kg. Overall, the lip -pressure method tends to estimate a higher flowing enthalpy compared to the Dynamic PT log method.

Figure 2. Estimated flowing enthalpy from Dynamic PT logs and Lip-Pressure Method, squares and boxes represent fields in operation while diamonds represent greenfields (left). Histogram of differences between methods showing positive skew(right).



Discussion

As observed, the estimated flowing enthalpy using each method does not exhibit a linear correlation. Several potential reasons for this discrepancy are listed:

- The use of pure water steam tables, such as IAPWS97, may not accurately represent the actual conditions. Dissolved gases and other minerals present in the geothermal fluid can alter the thermodynamic conditions at the flash point when using the PT logs approach.

- Non-condensable gases can influence the enthalpy estimated using the lip-pressure method. This method tends to reduce the value of the flowing enthalpy [3].
- The lip pressure method has been compared to the separator method. While a 95% confidence level is granted [1], other authors estimate an accuracy of +/- 15% [4].
- The flowing enthalpy is highly dependent on the liquid flow rate estimated at the silencer, especially when using a weir-box as a measuring device.
- Atmospheric separator sizing can be problematic. Since each well has unique fluid and enthalpy characteristics, even within the same wellpad, using a shared separator compromises the measurement of the liquid phase at wells with the highest mass flow rates. Some liquid droplets may be carried out at the steam plume, reducing the brine measurement and consequently overestimating the flowing enthalpy.
- When the flash point occurs below the production shoe casing, some saturated shallower feedzones could increase the overall flowing enthalpy, leading to misleading comparisons between methods. This is because the PT log approach does not consider all the fluid in the enthalpy estimation.

Despite these valid reasons, the lip-pressure method remains widely used for assessing geothermal wells in liquid-dominated reservoirs due to its simplicity and low cost. However, it is crucial to use the right-sized equipment and instrumentation to ensure accurate data.

Conclusions

For the wells analyzed in this study from four different geothermal fields in El Salvador, the lip-pressure method estimates a flowing enthalpy that is 5 to 20% higher than estimated from the P&T logs. The greater differences appear when the flash point is below the casing shoe. While the P&T log method provides a quick reference value for the flowing enthalpy, it lacks information regarding the mass flow rate.

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