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Can Geothermal Wells Go Cementless?

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ABSTRACT

Due to the high temperature cycles during its life, a geothermal well it is exposed to higher loads compared with conventional oil and gas wells.

A conventional well construction utilizes and relies on cement for annular isolation between the casing and the formation, the isolation effectiveness derives from the cement properties behavior in downhole conditions while is setting after a given time. To date only few alternatives to oil well cements have been economically imposed on the market.

Effective isolation is not always achieved with cement blends, for this reason alternative technologies such as metallic expandable systems derived from metallic packers can be integrated into casing string and provide the needed seal between casing and formation in the required depths.

Given the current tendency in geothermal well construction and completion to use the casing as production string (tubing) rather than adding another string for the production needs, a cementless well construction could enhance the geothermal well construction process while adding achieving maximum well integrity for a much longer time when compared with cement.

This paper will present some of the achievements in the well planning of cementless wells using metallic sealing units and will discuss possible future applications in geothermal fields.

1. INTRODUCTION

Geothermal well construction, is in many aspects similar to oil and gas well, however, there two major parameters that will significantly influence the decisional level: need of larger flow area (hence larger production casing size and in many cases the elimination of the tubing) and the presence of high temperature (in some cases higher than most of the high-pressure high temperature oil wells).

Although geothermal well construction is not easy to classify, due to the limited number of geothermal wells compared with oil and gas, few elements are always visible:

Production casing size tend to exceed the common oil and gas wells, which is a consequence of lower energy density and the require hot water flow.

- When centrifugal submersible pumps are in use, the upper section of the well will show even larger diameter.
- Recently there is a push for liner use in order to satisfy the 2 conditions shown above.

Figure 1 shows an example of a geothermal well construction. Please note that the open hole section depends on the geothermal reservoir properties and the final production option. Although an open hole is shown, a lot of modern geothermal wells worldwide are designed using cemented cased holes and perforations. A production liner is commonly used to cut costs, however, to improve well integrity and its high temperature resistance a production string is often used.

To safely exploit a geothermal resource, a connection between the surface and the producing target is created – the well. This well is done through the process of drilling, which consists of a sequential process of making a hole followed by running casing and cementing, followed by a smaller hole, and again running smaller casing and then cementing. This entire process is called well construction and its solely purpose is to build a long-lasting connection between surface and the target zone.

During the well construction, the engineers adjust the well plan to safely implement the best solution to reach the targeted depth without accidents and incidents. In general, a well construction schematic as presented in Figure 1 shows a telescopic structure with the largest casing set at the shallowest depth and the smaller casing reaching the total depth. During the construction, the casings are typically cemented in place. The objective of the cement is to fill the space between casing and wellbore and create an annular seal, preventing cross flow between formations, and mitigating annular fluid migration to surface.

Additionally, the casing shoe requires effective isolation (typically with cement), to enable the drilling process of the deeper section, a failed casing shoe can prevent the drilling process from being performed, as losses of drilling fluid and other operational problems may occur. All this isolation requirements are regulated by country specific entities.

Since the early drilling of wells, cement was adopted as the preferred annular isolation and casing to formation sealing method in the industry for better well productivity and well integrity assurance.

Well integrity and annular isolation play a key role in well performance and well completion in the oil, gas or geothermal industries, the cement is intended to provide hydraulic isolation, and prevent fluid flow between producing zones, protecting groundwater aquifers and surface sustained pressure (Loizzo and Sandeep, 2008, Al Ramis et al., 2020). However, the cement sheath alone is not always able to deliver an acceptable long-term solution for today's demanding drilling environment. Recently, advances in cement and well completion practices have significantly improved the quality of wells and extended their operating life. A possible future evolution of geothermal well construction is shown in figure 2, whereas the option of a pure monobore well construction will allow geothermal well drilling to reach almost any geothermal reservoir.

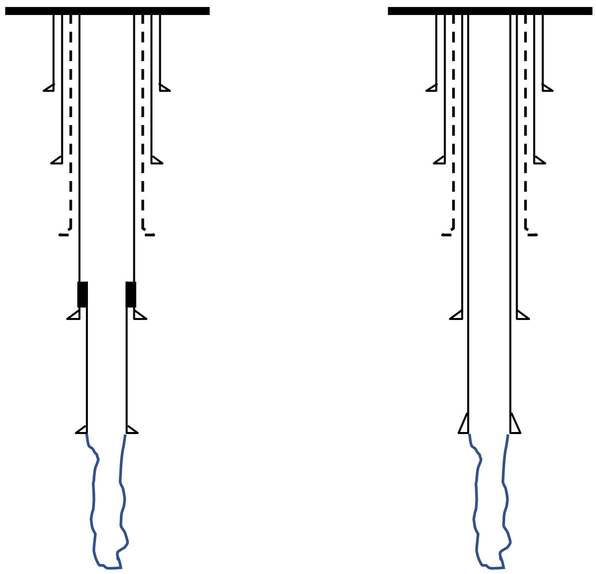

Figure 1. Geothermal Well Construction a general schematic left using production liner, right using production string (open hole section is optional)

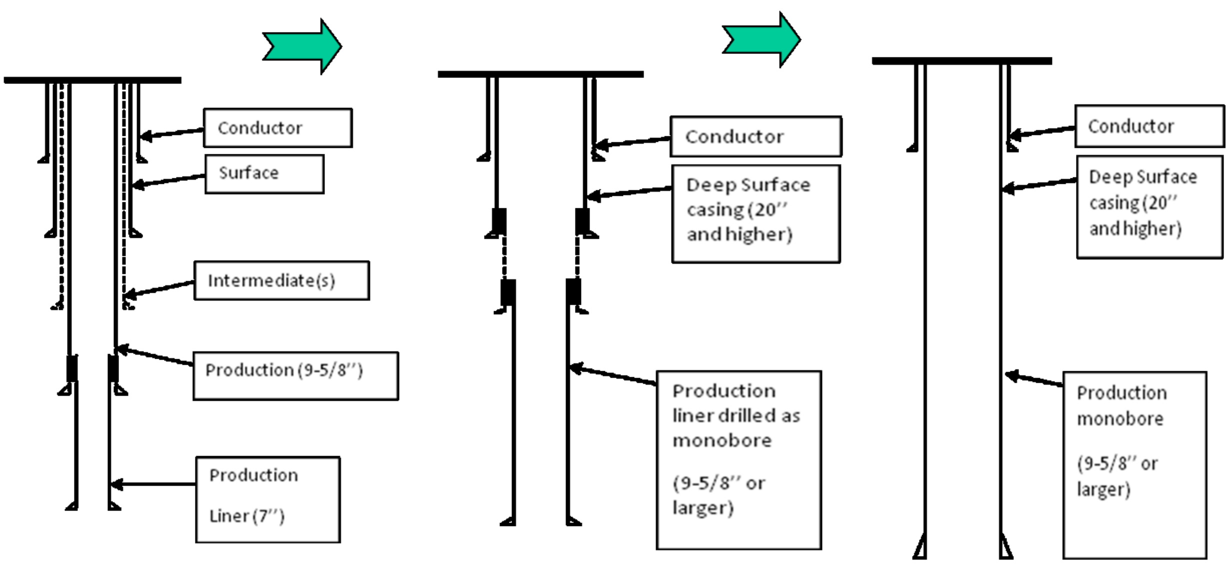

Figure 2. Geothermal Well Construction a possible evolution

2. WHY IS CEMENT USED IN A WELL?

The need of cement in well construction is first of all given by the following 3 main functions of the cement:

- Seal crossing formation and block fluid movement in vertical direction (low permeability and porosity)
- Support casing (especially surface casing) and provide mechanical support to impede axial movement
- Protect casing from corrosive fluids that may exists inside the pore space.

Beside this the following functions of cement must be mentioned:

- Keep the fluids from expanding in the annulus (casing collapse danger)
- Hold the casing string in place and avoid buckling (a very important aspect for geothermal wells)
- Displace the mud and uniformly occupy the annular space
- Pumpability (this is the main difference between oil well cements and civil engineering concrete)
- Create a strong bond to the formation and casing
- Long term resistance to downhole conditions.

When talking about geothermal wells, it is imperative that the cement will first be capable to withstand the high temperature for a very long time (life of the well estimated to exceed the oil and gas wells life of 30 years). Strength retrogression is normally compensated through the addition of silica powder or fly ash. However, the cement mechanical properties are affected (lower UCS) and time related degradation is still an issue. Furthermore, cement job complications and the casing poor centralization will generally lead to poor cement quality. Under the extreme geothermal well conditions the cement sheath will generally fail first mechanically (cracks or debonding) followed by long term strength degradation.

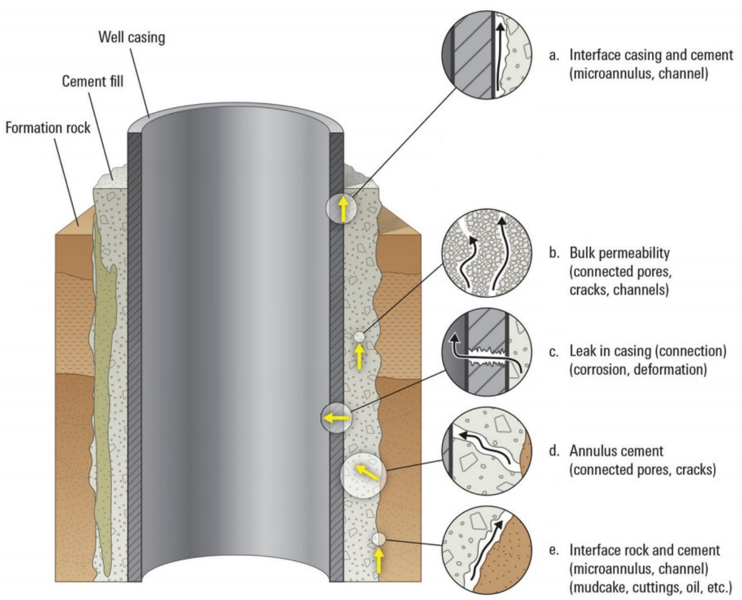

Figure 3. Potential Leak paths, including channeling, micro annuli and mud cake occur due to poorly executed cementing operations. (https://www.slb.com/-/media/files/well-intervention/industry-article/201705-os-bdt-promill-north-sea)

3. CEMENTLESS WELL CONSTRUCTION

Figure 4 shows a well construction concept using only the metal expandable packer (MEP) system in comparison with a conventional well. It can be noted that such a concept requires the MEP (at least one or two sections) at casing shoe of each casing string, while the surface casing can be run with a combination of MEP and cement or just MEP as shown in Figure 4. Although a through cement job is desired for most of the geothermal wells, it must be noted that this is not always possible, and the combination of the MEP with cement, can provide enhanced annular sealing, preventing the challenges shown in fig 3.

Since regulations are not always easy to overcome, the first approach is with the intermediate and production casing, thus the surface casing will still be cemented according to current regulations. The placement of the MEP will be designed in such a way that every strong and competent formation will have a MEP (typically less than 30 ft) installed. This solution will reduce the potential cross flow between formations. Please note that a MEP will also be installed at the casing shoe between the outer and inner casings, which will help fully isolating the annulus between the two casings and thus eliminating any potential sustained casing pressure source. In the situation where a filling material is required in the annulus, the MEP can be used in combination with cement or foam systems, since the effective pressure isolation is being provided by the MEP and not the cement itself. A precise placement of the MEP is based on better understanding of wellbore geology and rock properties and can be optimized just before running the casing string. To compensate for axial casing expansion (due to thermal elongation) prestressing of the casing strings is necessary. This prestressing is however, better controlled using the proposed metallic packer system since the setting of the packer can be also done in challenging zones with potential losses of cement. The setting process of the metallic packer system does not depend on the wellbore frac pressure and thus, will always ensure that the casing is run to the planned target depth.

As shown in figure 4, all annuli are kept open to surface, allowing for better control of the annulus pressure and monitoring of the well integrity during the life of the well.

Casing buckling can be obtained using shorter metallic packer systems along the critical zones. Nevertheless, the prestressing of the upper casing string is the best solution to avoid casing buckling during thermal expansion. The metallic packer system could be highly beneficial in casing pre-stressing, since does not need any setting time (wait ion cement) to allow the prestressing application, and thus pre-stress force can be much better controlled.

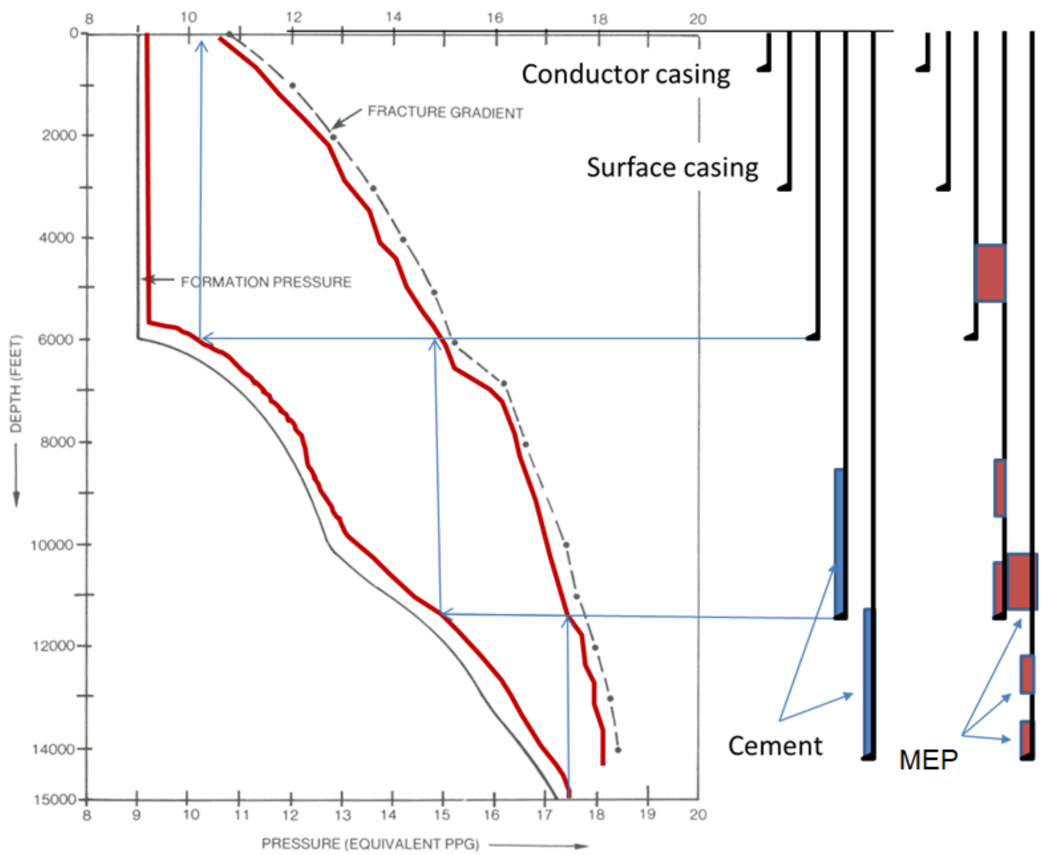

Figure 4. A comparison between conventional well construction and the newly cementless well solution.

A cement replacement with the Metallic Element Packers (MEP) was performed in an O&G well shown in fig 5, the previous wells demonstrated to have high risks of successful cementing due to the downhole conditions. The solution was to use over a 240m of MEP, 80 packers with 1,280 elements were successfully installed and expanded in a single step by applying pressure from surface. Moving from a cemented to a cementless liner has allowed saving directly four rig days compared to the best composite well: this represents 2.8 million dollars' savings. And compared to the average well (including NPT), the rig time savings are in the order of 10 days of rig time.

The method showed the following benefits:

1. Achieve substantial risk and cost reduction by:
    a. Removing the need to drill the extended shoe track (100m) into the water zone
    b. Eliminating the need to under-ream from 6 ½" to 7 ¼" to increase the success of the cementing operation

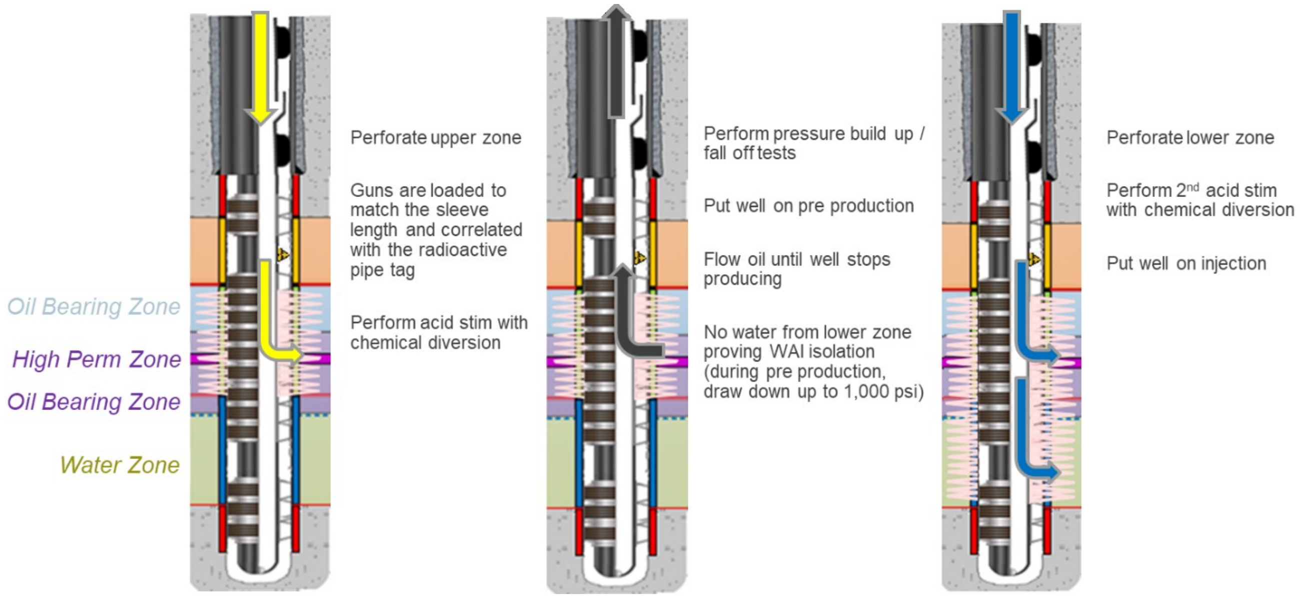

Figure 5. Replacement of cement by MEP

4. CONCLUSIONS

This paper shows a possible geothermal well construction using metallic packer systems, instead of the cement to seal the annular space and support the casing.

The proposal is first designed to be implemented for intermediate casing strings as well as for production casing. The method can also be used when a production liner is used.

Although this concept is still at concept phase, further work is currently under development.

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