USE OF ICE PLUGS IN GEOTHERMAL ANTI-SCALANT TUBING SYSTEMS

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ABSTRACT

Anti-scalant tubing is commonly used in geothermal wells to allow chemical injection of anti-scalant fluids from the surface, delaying scale formation downhole. This tubing is intended to be continuously exposed to severe well conditions creating a need for monitoring and inspecting the injection string periodically. One of the methods used to inspect the tubing is called tubing lift. This consists of retrieving part of the anti-scalant tubing string from the well. This procedure moves the localised stress point on the tubing string and also allows inspection of part of the anti-scalant tubing at the surface.

Over time, this excess tubing collected at the surface becomes problematic, taking up space at the wellhead, and needs to be removed. A common solution to this problem is to cut and re-join the tubing with the slack removed. Unfortunately, this process has the inherent risk that when the tubing is cut, for a short period, the well remains open to the atmosphere. To avoid this exposure, the alternative is to retrieve the entire tubing string followed by unspooling & spooling, cutting and re-running the string in the well. However, this is a timely and costly endeavour for such a small change in the anti-scalant tubing string.

To improve the cut and re-join process, the idea of a temporary well barrier was explored, and ice plugs were found to be a suitable solution to well containment. Ice plugs have been used in process industries in a variety of applications, but there currently exists no documented evidence of their use in geothermal anti-scalant tubing maintenance.

This paper discusses the use of ice plugs in geothermal anti-scalant tubing operations, and how they have provided a simple and inexpensive solution in contrast to a full tubing retrieval while still addressing the well control risk of the cut and re-join method.

1. A PROBLEM TO BE SOLVED

Injection of scale inhibitors into geothermal wells has been in use since the 1980s (Pieri, Sabatelli, & Tarquini, 1989). These systems have evolved over time. Early systems used by Mercury NZ Ltd involved a wellhead hung piping system with internal Inconel tubing. This system was upgraded in 2015 when Mercury changed their design to 3/8 in OD 2205 continuous tubing and in 2018 even introduced a maintenance plan for their tubing strings. Mercury has thus far been through three generations of anti-scalant tubing designs.

Today in New Zealand geothermal fields, an anti-scalant tubing system commonly consists of passing a small diameter (1/4 in to 3/8 in OD) continuous tube of stainless steel (or another corrosion-resistant alloy) through a packing gland and suspending it from the wellhead to the depth of interest. At this depth, scale inhibitor is continuously injected during the life of the well.

The generalised system described above has not always been the case.

In New Zealand, this system has been referred to as anti-scalant tubing. Despite the anti-scalant tubing being made from corrosion-resistant material of high yield strength, the geothermal downhole conditions in New Zealand are such that this anti-scalant tubing can become damaged during its life. If it is not monitored and managed correctly, the tubing string can break, leaving a fish in the well. The well must then be quenched, the tubing string recovered, and a new anti-scalant tubing system installed to prevent the on-going scale formation.

Each geothermal operator in New Zealand has their own monitoring plan for anti-scalant tubing. Although the frequency of inspections may vary between clients, the methods used to monitor the anti-scalant tubing integrity are similar. One of the monitoring methods used to prevent anti-scalant tubing failure is called a tubing lift. A tubing lift involves pulling the tubing out of the well by ≈10m and conducting an inspection of the retrieved section. The purpose of a tubing lift is to regularly move localised stress points on the tubing string with the objective of avoiding wearing, breaking, and extending its operational life.

Over time the amount of retrieved tubing accumulates at surface. An example of this is shown in Figure 1.

Figure 1: An image showing a wrap of anti-scalant tubing which has accumulated at surface from multiple tubing lifts.

This excess tubing at surface is difficult to handle, looks untidy, creates a trip hazard, restricts access to the wellhead area, gets coiled at surface and tends to wear due to vibration rubbing when not well secured, leading to a surface discharge. For the mentioned reasons, geothermal operators often remove the excess tubing at surface as part of their well monitoring and maintenance plans. Herein lies the problem which the paper intends to address.

The anti-scalant tubing does not contain any non-return valves or pressure control apart from the tubing itself. Therefore, the tubing cannot be cut and re-joined to remove the excess, without having any barrier that maintains the well under control.An alternative to this is to retrieve the entire tubing string followed by cutting and re-running the string in the well. This type of operation adds operational risk and cost, given that it would require a wireline unit, a spooling unit and crew to complete the task. In order to address this problem, the idea of using a pipe freeze as a temporary barrier during a 'cut and re-join' operation was proposed.

2. PIPE FREEZE

2.1 History

According to Wild Well Control (2020) "Pipe freeze services have been used for many years to place a temporary ice plug barrier in tubulars (tubing, drill pipe, casing) when it is the only viable option to maintain pressure control while allowing remedial repairs to be made to surface equipment or tubulars." (Wild Well Control, 2020).

The method by which the pipe freeze functions relies on having a freezable medium inside the pipework of interest. Extremely cold temperatures are applied to the working fluid by means of a cooling jacket, and the working fluid freezes in the section of the pipe covered by the cooling jacket, forming a barrier to the pressure on both sides of the ice plug. This barrier then allows repairs or modifications to be made on the process system of concern.

Cryogenic Freezing has proven to be a quick, cost-effective, and safe solution when a temporary barrier in the wellbore/component is needed. It has even been used on large diameter pipework (Yugay, et al., 2018).

2.2 Application to Geothermal

In the oil and gas industry, there are some restrictions on the pipe freeze process. "If there is flow, any void, or gas or hydrocarbon-based fluid present in the freeze area, a freezable medium must be injected into the ID of the component" (Wild Well Control, 2020). However, in the case of geothermal wells, the anti-scalant tubing is filled with geothermal condensate prior to beginning the pipe freeze. Since the condensate is essentially water, no special chemical injection is required for the pipe freeze to be effective. Other major advantages of the pipe freeze technology for anti-scalant tubing surface maintenance include:

- The tubing maintenance crew is only required at the wellsite for a fraction of the time required if the entire tubing string was retrieved to surface, cut and run-in-hole again. This reduces the overall maintenance cost for the tubing system.
- The well pressure is entirely contained during the 'cut and re-join' operation. The risk of the tubing crew being exposed to well pressure is minimised.
- Reduced operational risk compared to previous alternative methods. The combination of the pipe freeze and 'cut and re-join' methods not only contains the well pressure but also eliminates any downhole operation.
- The anti-scalant tubing has suitable mechanical properties to be used for a pipe freeze. In fact, pipe freezes have been successfully performed on aluminium, copper, stainless steel, mild steel and even polymer pipes (Martin-Nown, 2008)
- The freeze plug length can be adjusted if required by using different jacket sizes.
- The pipe freeze system is easily transportable. All equipment required for the pipe freeze can be mobilised in a light vehicle.
- The efficiency of the pipe freeze minimises the time during which scale inhibitor is not being injected into the well.

2.3 Design and Planning

This section outlines the design, planning and trials completed by the authors to qualify the system for use. As is required for all geothermal wellsite activities in New Zealand, a standard-operating-procedure (SOP) and job-safety-analysis (JSA) for the task needs to be developed.

Trials were conducted in the authors facility to identify the most suitable cooling fluid type, cooling fluid volume, hand tools, procedure, PPE and training needed to successfully implement the idea.

Some of the tests performed include:

- Creating ice plugs with different cooling and working fluids
- Pressure testing the plugs (up to 200 bar)
- Timing the life of the ice plugs (≈1.5 hr at 10 °C ambient)
- Conduct the tests with various tubing sizes (1/4 in and 3/8 in)
- Trialing the process with different hand tools and procedures to develop an efficient and safe SOP.
- Obtaining suitable equipment designed for performing tubing freezes based on specific task requirements for New Zealand geothermal applications.
- Conducting training with staff to ensure they understand the JSA and SOP and were deemed competent to perform the task.
- Conducting a mock-operation for the operator as a 3rd party verification of the safety controls put in place to execute the operation.

3. IMPLEMENTATION

This section outlines the process of performing a pipe freeze on geothermal anti-scalant tubing in New Zealand. The process outlined here has been generalised for simplicity. However, the exact piping and instrumentation of the anti-scalant tubing system is operator dependent.

The process begins with selection of candidate wells with photos of the wellsite or a site visit before mobilising the crew, to finalise operational planning.

During the operational planning, verify the following:

- Verify how much tubing the operator requires left on surface.
- Verify tubing will be purged and fully loaded with geothermal condensate (i.e. water). No acid/scale inhibitor should be present in the system.

- Verify the dosing pumps pressure gauges are functional and correctly operating.
- Verify the pressure downstream of the ice plug.
- Review job procedure and timing with the operator.

A generalised layout of the anti-scalant tubing system is shown in Figure 2. Before commencing wellsite operations, the tubing crew needs to verify with the well operator to ensure the anti-scalant tubing has been displaced to a suitable carrier fluid and the dosing pumps have been disengaged.

This is then confirmed visually on site by inspecting the dosing system gauges. Depending on the geothermal operator, a lock-out / tag-out procedure may be required.

Once the pumps are confirmed off, the dosing system is isolated using the system valves, and any remaining pressure bled off. A pressure gauge may be installed to provide the tubing maintenance crew with pressure monitoring during the pipe freeze (see Figure 3).

Figure 3: Pressure gauge and bleed off point

The ice bag is then placed on the tubing in the desired location (see Figure 4).

Figure 4: Ice bag on the anti-scalant tubing

The cooling fluid is then connected to the ice bag system and allowed to enter the ice bag. The cooling medium is obviously very cold, and proper PPE needs to be worn by those involved in the operation.

As the cooling fluid begins to form the ice plug, the pressure gauge must be continuously monitored to verify isolation. The ice plug is considered set provided the pressure reading remains at zero, and the ice bag remains full. Once the ice plug is complete, the tubing can be cut (see Figure 5).

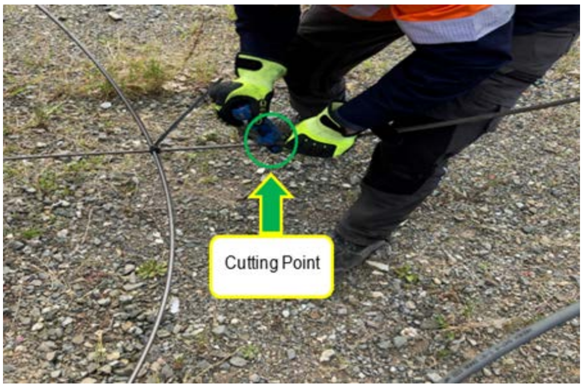

Figure 5: Tubing crew cutting the anti-scalant tubing

Once the cut is complete, the anti-scalant tubing can be re-joined. Once the tubing has been reconnected, the pressure gauge and bleed off assembly can be removed, the ice bag removed (see Figure 6) the dosing system valves re-opened and the well handed back to the operator.

Figure 6: Ice bag removal

4. IMPROVEMENTS

During the research and development of the pipe freeze procedure, a number of improvements were identified. Some of those are included here. Most of the improvements relate to personnel safety.

The ice plug melts exponentially faster without the ice bag in place. It must not be removed until the dosing system is completely connected. A few minutes after the bag gets removed the plug melts, pressurising the system compared to ≈1.5 hrs if it remains in place.

The ice bag needs to remain full of ice to ensure the integrity of the ice plug. The ice bag is confirmed full by filling it with the cooling fluid and squeezing the bag with a hand using leather insulated gloves.

5. CONCLUSION

This paper discussed the use of ice plugs as part of the geothermal anti-scalant tubing lifecycle. Ice plugs have helped address a number of issues, including wellhead personal safety and anti-scalant tubing management; it does this using a simple yet effective method. Although the uptake of such a technique is operator dependent, this paper forms the first documented evidence of the technique being implementated in New Zealand. A campaign of pipe freezes is planned with one New Zealand geothermal operator during the remainder of 2020. This paper discussed a number of topics related to pipe freeze technology, including background and history, design and planning, job execution, and improvements.

ACKNOWLEDGEMENTS

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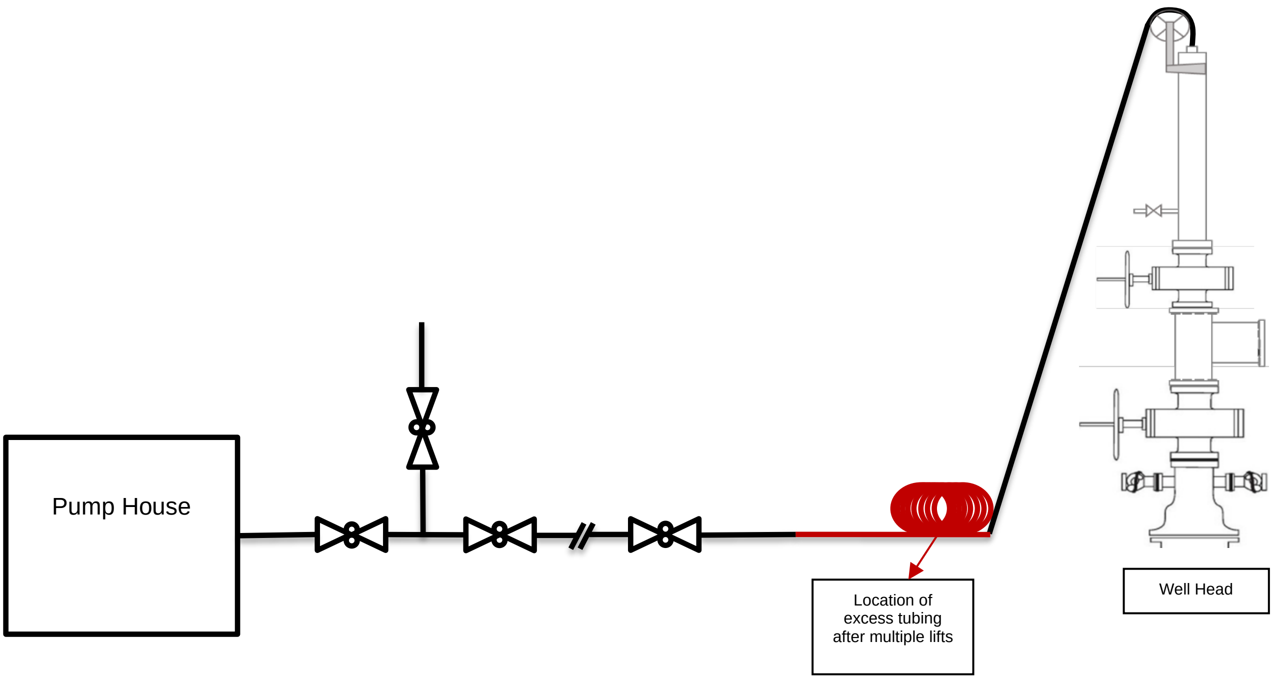

Figure 2: A generalised P&ID for the anti-scalant tubing system prior to installation of the pipe freeze equipment