DEVELOPMENTS IN ANTISCALANT DELIVERY TECHNOLOGY

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ABSTRACT

This paper discusses the causes of scale formation and the evolution of antiscalant chemical injection systems in geothermal wells with examples of antiscalant projects. It covers the benefits of antiscalants such as reduced maintenance costs; stinger design; and the evolution of pumping systems in New Zealand and overseas. Calcium carbonate and other chemicals often deposit in well linings where two-phase geothermal fluid is present. The scale rapidly forms a rock-like substance on the side of the well casing and reduces the well's production capacity over time. The traditional solution to counteract this build-up was to "work over" the well with a drilling rig that reamed out the deposits in an attempt to improve the well's production rate. MB Century has developed antiscalant injection systems for the last 25 years. The antiscalant systems have been proved to be practical and cost effective solutions to reduce the cost of major well maintenance and maintain production. This paper also reviews the various stinger designs used in geothermal antiscalant applications.

1. INTRODUCTION

1.1 History of pipe scale

Natural stalactites in limestone caves are formed by the deposition of calcium carbonate which is precipitated from mineralised water solutions. This mechanism has been causing problems in piping since the invention of plumbing. Water scale issues and solutions have been recorded since early Roman times with scale forming in aqueducts. Historically scale has been mechanically removed when its build-up forms a substantial restriction in flows. In order for large scale deposits to form the following conditions must exist (Brown and Gould 1985):

- Fluids with high concentrations of minerals that leach from the geology of the aquifer into plumbing systems.
- Heating, boiling evaporation and/or mixing of fluids.

The formation of scale can pose serious problems in mechanical plant such as boilers, cooling towers, heat exchangers and other equipment that handle water. Scale is limited by controlling and monitoring mineral concentrations to avoid scale formation, but this is usually followed by costly shutdowns to mechanically remove scale or by mechanical breakdowns.

1.2 History of casing scale in wells

Geothermal waters with abundant hot and heavily mineral laden water are famous for their ability to form silica and calcite natural features.

Geothermal wells have major problems with the formation of scale at the point in the well where the fluid is changing from liquid to a steam/liquid fraction, known as the flash point. Historically this build-up was mechanically removed by a "work over" where a drilling rig reams out the well casing to remove any deposits in the well liner.

2 ANTISCALANT SYSTEMS

2.1 The early days

The first geothermal antiscalant trials in New Zealand were undertaken by the Geothermal Research Centre of the Department of Scientific and Industrial Research from 1984 in the Rotorua geothermal field on domestic heating bores that required annual mechanical reaming to remove calcium carbonate (Brown and Gould 1985). Studies on production well #RT885 showed a cost saving of over 30 percent when fitted with antiscalant systems. These initial wells at 107 to 130°C were comparatively cool compared to some of the more recently developed geothermal fields. The antiscalant used was a polyacrylate, FLOCON247 by Phizer, which was designed for scale control in desalination plants and cooling towers. It congeals if exposed to temperatures of over 100^0C for extended periods.

The system installed on well #RT885 initially used ½" galvanised water pipe to a depth of 130 meters. This was replaced with ¾" stainless tube after blockages of brown sludge occurred. The sludge was found to be a compound of:

- Congealed antiscalant from operation at the maximum design temperature for an extended period due to the pipe sizing.
- Iron rust from carbon steel pipes in the town's water supply and in the down-hole system.
- Silica which naturally occurs in high levels in Rotorua's town water supply.

2.2 Kawerau Geothermal Field, New Zealand

The geothermal production well KA35 at Kawerau provided the next big development of an antiscalant system. The well had a temperature of 270°C, a depth of 1,000 meters and scale which reduced the well output by 70 percent over a 12 month period (Bloomer and Cottrell 2001).

Before introduction of antiscalant injection in well KA35 the following two techniques were used:

- Well liners were reamed downhole and then pulled to the surface. Scale in the slots of the well liner was water blasted out and then the well liner was reinstalled down the well.
- Well liners were water blasted in situ with a specially designed down-hole water blasting tool.

In 1989 a new high temperature antiscalant, sulphated acrylic copolymer, was trialled on well KA35 with 900 to 1,000 meters of ¼" Incoloy 825 down-hole tube. The new chemical provided good results in reducing scale but the down-hole tube failure was problematic and resulted in trials being stopped.

In 1997 new trials on well KA19 were undertaken using woven strands of galvanised improved plough steel (GIPS) to form an armoured sheath over a ¼" alloy tubing to allow reliable delivery of antiscalant below the flash point of the well at depths of over 1,000 meters.

Well KA35 was fitted with a GIPS armoured tube which still suffered from failure due to the fatigue from the well's natural oscillation of two-phase slugs and the high discharge velocities of the well. This was overcome with a "down-hole stinger", constituted of a heavy pipe shroud around the tube in the turbulent flow at the wellhead tee. This system has proved to be successful at well KA35.

Well KA30, which was connected in 2012, and other Kawerau wells are being fitted with a down-hole antiscalant system that has a continuous tube outer protecting a 5/16" stainless tube inner. This is seen as a more reliable option than the GIPS armoured tube and has been used successfully since 1999 when a similar system was installed in Dixie Valley in the USA (Blackwell, Golan and Beniot 2000). Screwed 1.9" casing has also been used at Kawerau as the other protective tube.

2.3 New Crest Gold, Lihir, Papua New Guinea

New Crest Gold operates a geothermal power station and associated wells on the island of Lihir off the coast of Papua New Guinea (Koorey and Rock 2002). The geothermal fluid has high levels of:

- Chloride due to the seawater in the aquifer.
- Calcite from a limestone aquifer.

The down-hole tube used for trials at Lihir was originally just ¼" Incoloy 825 tube to a depth of 1,280 to 1,442 meters but the high chloride levels resulted in premature failure of the tubes and were replaced with GIPS armoured tube.

Some of the wells at Lihir have a high deviation away from vertical. This introduced additional problems of the tube being in contact with the well casing in some areas and required the use of wheeled sinker bars to travel reliably to below the flashing zone of the well (Koorey and Rock 2002).

Due to the high cost of getting a drilling rig to Lihir, New Crest Gold has invested heavily in antiscalant systems. They have used containerised pump stations for individual wells and a central pump station that incudes:

- Fully automatic mixing of chemicals.
- Steam condensate recovery systems for making diluted chemical mixes.

Lihir had problems with corrosion of the GIPS armour just above the wellhead gland packing due to corrosive well fluid leaking and mixing with oxygen. The solution to this corrosion was to terminate the GIPS inside the wellhead in a low oxygen environment and to just have the inner alloy tube passing through the gland.

2.4 Contact Energy, Te Huka, Taupo, New Zealand

Contact Energy recently (2013) commissioned a new five-pump antiscalant injection system with four high pressure chemical pumps to wells TH 06 and TH014 at Te Huka power station on Tauhara field near Taupo. It incorporates a demineralised water flush system which can automatically purge the injection tube of chemicals to reduce the chance of blockages.

Some of the features of the Te Huka system which we included in the design to improve performance, reliability, and operator and environmental safety are:

- Winterising the system against freezing conditions which can stop the flow of chemicals down the well resulting in a catastrophic congealed blockage in the down-hole tube.
- Safety showers and equipment for clean-up.
- Condensate flush systems with standby high flow and high pressure pump to prevent blockages should the antiscalant chemical pumps malfunction.
- Substantial storage capacity of mixed chemicals and condensate to reduce operation costs.
- The well tubing systems used are plain ¼" alloy tubing with no protection.

2.5 Ngawha, Top Energy, New Zealand

Three production wells in the Ngawha field have been fitted with GIPS tubing This tubing has had very good long term results at Ngawha with two wells commissioned in 1998 and the third system installed in 2008. In this time there has been no tubing failures and only one tube has been replaced.

Ngawha uses a central pump station. Surface tubing runs are up to 900 meters long.

3 DESIGN CONSIDERATIONS FOR ANTISCALANT SYSTEMS

3.1 Mechanical design

Common mechanical root cause failure points of antiscalant systems are abrasion, fatigue and corrosion of the tube at the wellhead where the tube is supported (Buning, et al. 2000). According to current New Zealand best practice these failure points can be managed with good engineering design and operational techniques such as retracting the tube approximately 200 mm every two months to reduce the chances of fatigue or corrosion failure of the tube at the wellhead.

Operational experience has shown that a high pressure, viscous fluid, blended with a fibrous mix, can be used to form a pressure-containing seal around plain tube and woven GIPS armoured shielded tube at the wellhead gland.

When designing antiscalant systems for wells where slugging, high discharge velocities, or corrosive environments occur we recommend additional protection of the tubing. This additional protection can be achieved through:

- The use of high quality materials such as Incoloy 825 stainless steel for down tube.

- Tubing wrapped in armoured GIPS which will however fray over time as the galvanising protection is lost.

- A protective pipe shroud (stinger) protruding down into the well from the wellhead past the turbulence of the discharge point.

- Concentrically installing the tube inside a small bore pipe to provide mechanical protection. This arrangement will reduce the well's performance due to a reduction in the useful area in the well casing. But the outer pipe may be useful for stimulating the well with compressed nitrogen. The tube sizing should be kept small to maintain velocities and to reduce transit times.

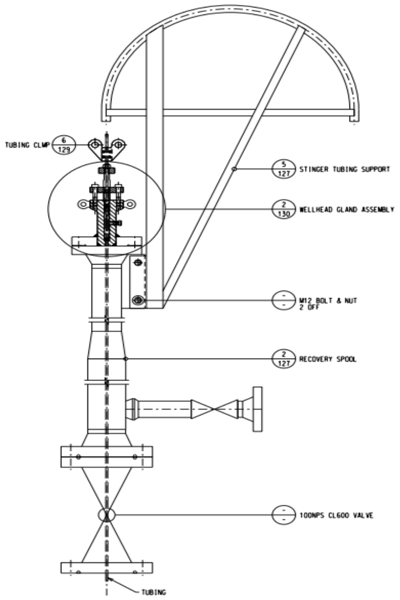

Figure 1: Typical gland assembly installed above the master valve. This example includes a recovery tube used on a plain tubing system run inside larger protective tube.

The majority of antiscalant injection systems in service in New Zealand use Milton Roy single cylinder positive displacement piston pumps which produce pressure pulses that can cause equipment damage. High pressure nitrogen-filled dampers installed at the discharge of the pumps are a proven method of smoothing these pulses.

Figure 2: Four-pump dosing skid prior to installation with a stinger in the background

3.2 Process design

As well as mechanical design, process design is also an important aspect of well operations. The following should be considered:

- Using condensed steam or another clean water source for chemical dilution. Minerals in dilution water can form scale in the injection tubing.

- Managing the residence time of the chemicals in the well tubing. Antiscalent chemicals can form scale in the injection tubing if exposed to heat for too long.

- Undertaking injection rate trials to find the optimum injection rate. Effectiveness of the chemical is measured by sampling for calcite formation in the well's production fluids.

- Reducing the risk of foreign matter entering the high pressure system by using particle filters on the low pressure system.

- Ensuring good mixing of chemicals with dilution water before pumping.

- Flow metering on the low pressure side of the pumps through tank level monitoring.

- Covering the tanks to keep them clean of dirt and insects which are attracted to some of the antiscalant chemicals or by water in dry areas.

- Ensuring good stock rotation of antiscalant chemicals as they can stratify over time.

- Stirring old stock of antiscalants to mix any layers of water and chemicals before use.

- Installing pressure damping systems with piston pumps as the pressure pulses are suspected of causing premature failure in tube fittings and instrumentation.

- Using centralised pumping stations that distribute mixed chemicals from a central pump station to a number of wells in tubing that is riveted onto the cladding of the field pipes. This provides a cost effective and practical solution. Lihir has 18 centralised pumps serving multiple wells distributed across a wide geographical area.

- Data logging the injection pressure to allow flow restriction in the antiscalant system to be monitored and and to provide information and alarms to enable the restrictions to be flush out before they become blockages.

- Installing high power purging pumps to allow the tubes to be flushed with demineralised water to rinse the system of restrictions and to purge the line of chemicals before shutting down the antiscalant system for maintenance.

- Installing permanent high pressure nitrogen gas purging systems to purge chemicals and blockages quickly. The size of an obstruction can rapidly increase with time and once the fluid flow has stopped the chemical in the tube may congeal quickly at high temperatures.

4 THE FUTURE

As there are a number of tubing systems in use in New Zealand at this time, it will be interesting in to see which proves to be the most reliable and cost effective.

Should wells get deeper and hotter and have higher flows in the future, antiscalant systems may require:

- New chemicals to withstand long transit times and temperatures exceeding 270°C.
- Changes in the wellhead design to reduce turbulence at the wellhead tee.

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