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The Use of Calcite Antiscalants at Rotorua Geothermal Field

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Abstract

A large fraction of the low pressure domestic bores in Rotorua suffer from calcite scaling. The problem is sometimes so severe, that wells have to be mechanically reamed every six weeks. We have tested the use of threshold antiscalants to control the calcite deposition. The experiment ran for over eight months and there is no sign of any calcite buildup, either in the well or in the surface pipework. Previously, the well had required reaming every three months.

Introduction

One of the most persistent problems in the exploitation of geothermal energy, is that of calcite scaling. The problem is apparent in many water dominated geothermal fields around the world. The worst case is probably at Kizildere in Turkey, but calcite deposition remains a problem in Chile, Japan, the U.S.S.R., Philippines, some of the U.S. fields, Mexico and New Zealand. In New Zealand, Ngawha, Kawerau and Broadlands experience severe calcite scaling.

Calcite deposition is also a major problem in the shallow domestic wells of the Rotorua geothermal field. Of ~350 wells in the Rotorua area, nearly 300 require regular maintenance for the effects of calcite deposition. The central and western sections of the field seem to be particularly affected.

Recently, a method for reducing the amount of calcite scale has become available. This involves injecting a small amount of a 'threshold antiscalant' into the geothermal fluid before flashing. The polymer inhibits the growth of crystal nucleii, and increases the solubility of calcite. Because of the practical difficulties involved in dosing the deep (-1000 m) wells at Kawerau and Broadlands, it was decided to test the effectiveness of the antiscalant in one of the more shallow Rotorua wells.

Chemistry of Calcite Formation

Calcite ($CaCO_3$) is unusual in that it has retrograde solubility, i.e. it becomes more soluble with a reduction in temperature. It may seem therefore, that as a geothermal well is discharged and the temperature is lowered, there should be no problem with calcite deposition, since it becomes more soluble at the lower temperature. Where the fluid is conductively cooled without stearn formation, then this is the case.

Calcite becomes more soluble when dissolved carbon dioxide (CO_2) is present in the solution. As bicarbonate (HCO_3^-) and $CO_{2(aq)}$ are the common species present at the pH of geothermal fluids, the calcite solubility can best be represented by the equilibrium:

$$Ca^{++} + 2HCO_3^- = CaCO_3 + CO_{2(aq)} \quad H_2O$$

When flashing takes place, a large fraction of the carbon dioxide previously dissolved in the water is distributed into the vapour phase. This lowers the solubility of calcite, which then crystallizes out of solution onto the casing. The wells in the central and western areas of the Rotorua geothermal field have a high carbon dioxide content which explains the predominance of calciting bores in these areas.

Experimental

The test was carried out at Bore RT855. This well is drilled to a depth of 130 m and cased to 120 m. The bore supplies heat energy requirements for six households, and prior to the test required reaming every three months. Bore RT855 is a low pressure bore which requires air lifting to start, but is self-sustaining when flowing. This enabled the bore to be easily collapsed and restarted after periodic inspections. The spent geothermal fluid is piped to a number of reinjection or 'soak' bores. Valves were fitted to these, to enable the total flow to be measured.

A sample of the water discharged at atmospheric pressure as well as a steam sample were collected. The analysis are given in Table 1.

TABLE 1

W.H.P. = 0.45 Bg, **Sep.** Press = 0.35 Bg.

Water				Steam		
pH_{20}	=	8.29		CO_2 =	1095	mmoles/100moles
Li^+	=	1.5	ppm	H_2S =	164	
Na^+	=	369	"	H_2 =	12.1	
K^+	=	24	"	N_2 =	68	
Ca^{++}	=	9.8	"	CH_4 =	3.7	
Mg^{++}	=	0.07	"			
Cl^-	=	310	"			
$SO_4^=$	=	54	"			
B	=	2.9	"			
SiO_2	=	210	"			
$HCO_{3(t)}$	=	291	"			
H_2S	=	85				

The temperature of the water feeding RT855 has been measured at 125°C. The wellhead pressure corresponds to about 107°C. It is possible to estimate the degree of calcite supersaturation using the analyses in Table 1. The calculations show that the solution is four-fold supersaturated with calcite when flashed to 107°C.

The dosing material used was FLOCON 247 manufactured by Pfizer Chemicals and originally designed for use in desalination plants. The manufacturers recommend a dose rate of 4 gms per tonne of fluid. The measured bore discharge was ~50 tonnes/day, which required a dose rate of ~10 mls/hour. With the equipment available, it was not possible to inject at this low rate, therefore the antiscalant was diluted to 1% v/v with water to enable more accurate metering of the solution.

The wellhead cap was altered to take a dosing pipe, which initially consisted of 19 m of galvanised 12 mm pipe, but was eventually changed to 19 m of 12 mm stainless steel pipe. A foot valve with a release pressure of 3 Bars was fitted to the bottom of the dosing pipe to stop siphoning of the dosing fluid and to stop geothermal fluid entering the dosing line. From temperature and pressure runs in the well, it was estimated that the dosing solution was introduced ~5 m below the flashing point. The dose rate was initially monitored by measuring the time taken to pump a known small volume of dosing solution. A coarser measurement was obtained by noting level changes in the bulk supply tank. The injection line pressure at the wellhead was 1.20 Bg under normal running conditions. A schematic of the dosing apparatus is shown in Fig. 1.

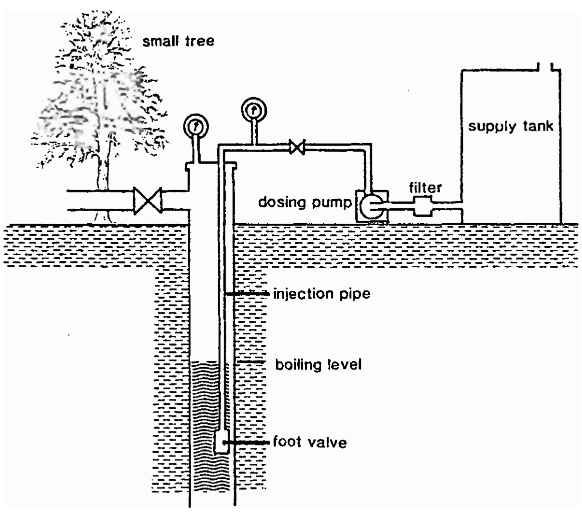

Fig. 1: ***Schematic of*** *dosing* ***experiment.***

Prior to starting the experiment, the well was reamed to 30 ft and the surface fixtures - pipes, valves, etc., were cleaned. The flowrate was measured at 86 tonnes/day and the dose rate was initially set at 3 ppm.

Results

Dosing with FLOCON 247 commenced in 1985. After only 12 days operation, the injection line pressure became very high. When the bore was collapsed and the injection line inspected, it was found to be blocked with a brown sludge. The deposit was amorphous to x-rays and gave a 69.78 weight loss on ashing. The residual consisted of 50% iron and 30% zinc. There were no blockages in the above ground dosing lines, and the deposit seemed to form where the solution became heated by the well discharge. The foot valve release pressure was increased to prevent any possibility of the dosing solution flashing.

It was thought that the blockage was due to reaction with the galvanising zinc. Since this had all been consumed, the dosing pipe was reinserted into the well, the well was restarted and dosing recommenced.

During the next few weeks, the injection line pressure, was still rather variable and finally after 45 days total the well was collapsed for a full inspection. This showed that there was no detectable calcite in any of the surface pipework. As well, the control valve for the well was also calcite free: this had previously been a trouble spot for calcite deposition. The injection line was covered with a fine black deposit of sphalerite (zinc sulphide). The surface piping was covered with a fine deposit of pyrrhotite, wnich is a common corrosion product encountered in geothermal systems. The dosing line was again almost completely blocked with a light brown sludge similar in appearance to that observed previously. The injection pipe was replaced by 12 cm 316 stainless steel pipe, and the experiment was restarted.

After only a further 15 days, the injection became blocked, and the deposit once again contained large amounts of iron. Since the stainless steel pipe was not corroded, it was reasoned that the iron was being dissolved in the steel storage tank and was reacting when it encountered the higher temperatures. Consequently, the steel tank was replaced by a plastic drum and a new dosing solution prepared. There were no further problems with blockages in the injection line.

The bore was again inspected after a total running time of 127 days. Once again, there was <u>no</u> detectable calcite deposition and there was the same thin film of pyrrhotite present on all of the surface pipework. The control valve was completely clear of any deposition.

Throughout the test to this stage, the pump settings were not altered. However, seasonal variations in the flow of the well (Fig. 2) meant that the dose rate was not constant and in the early stages, it was erratic due to the pipe blockages. In the latter stages of the first 127 days the dosing was regular and the does rate was ~2.5 ppm.

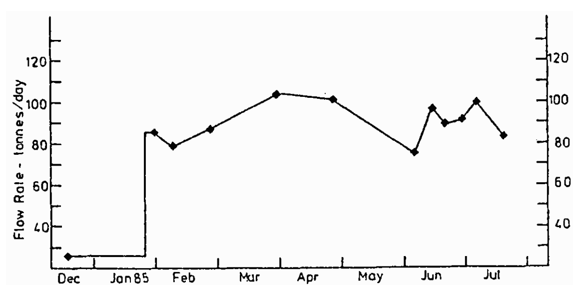

Fig. 2: *Measured* ***output*** **of** *RT885.*

For the final period, the dose rate was reduced to ~1.9 ppm. The dosing ran smoothly till the end of the experiment after a total elapsed time of 233 days. After this time,

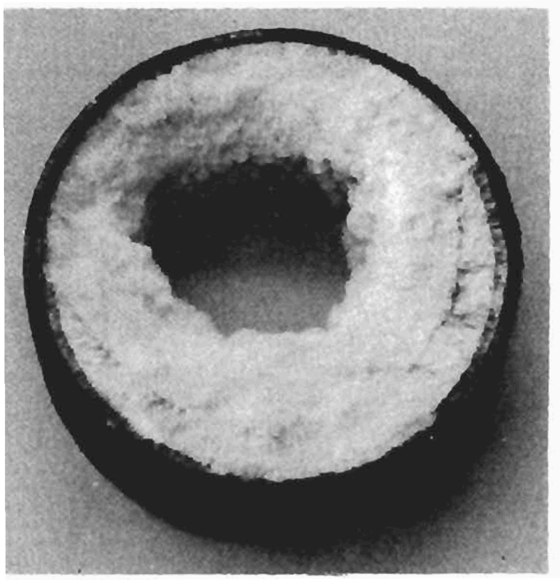

Fig. 3: Calcite scale produced after 112 days prior to dosing.

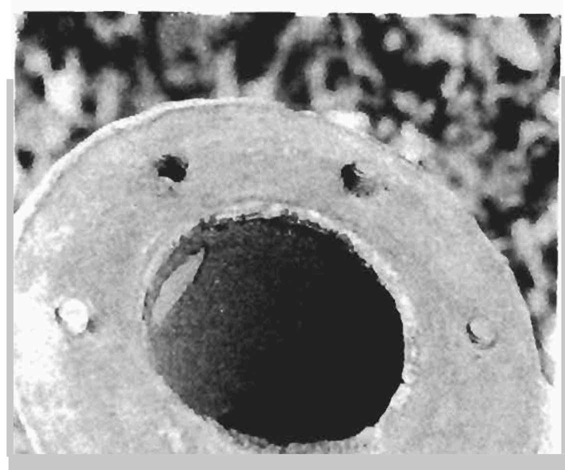

Fig. 4: Pipe in same position as Fig. 3 after 127 days operation with antiscalant.

the bore was collapsed, and inspected. Very small (<1 mm) crystals of calcite had formed in the pipework downstream of the control valve, however these crystals were sparsely located and not very adherent. The valve was completely clear, and a 3½" 'go-devil' run showed that the bore was clear to bottom hole. (The well is lined with 4' casing.) A test section of surface pipework had shown less than 0.05 mm decrease in diameter during the last 106 days of the experiment. There was no massive calcite scale.

Discussion

The FLOCON 247 has been very successful in completely inhibiting the growth of calcite scale, as is shown very dramatically in Fig. 3 and Fig. 4. There were no detrimental effects to the well, surface piping, environments or general use of FLOCON 247. From the appearance of very small calcite crystals at the lower dose rate, we would assume that ~2.5 ppm is a minimum dose rate for the particular well that we used.

The dosing solution is moderately acidic and appears to attack carbon steel. Consequently, storage tanks must be constructed of some inert material. Pressure must be maintained in the dosing line, as the antiscalant is an aqueous solution and boiling has to be avoided.

The price of FLOCON 247 varies, depending on freight rates and the U.S./N.Z. exchange rate. The estimate for the N.Z. selling price is NZ$8.75/kg. Assuming a dose rate of 2.5 ppm and a well flow of 100 tonnes/day, then the cost of FLOCON addition is $2.20/day. The only other running costs are pump and injection line maintenance. Initial capital costs are ~$1000.

Before the experiment, RT855 required reaming and acid treatment approximately four times/year at an average annual cost of $2300. Dosing with FLOCON 247 has an annual running cost of $800.

Two problem areas arise when scale-up to deep geothermal wells is contemplated. The first and most difficult is the method of injecting the antiscalant into the well below the point of flashing. The second problem is that the substance is decomposed slowly by higher temperatures and has a limited useful lifetime at temperatures in excess of 200°C. The latter problem could be solved by having low residence times in the dosing pipe, and this may place constraints on how the first problem is tackled.

However, dosing of deep wells is economically attractive. The material costs amount to $52,000/yr for a 250 tonne/hour well dosed at 3 ppm. This compares with $75,000 to ream the well - an annual event. As well, in the dosing system there is no reduction in production.

Acknowledgements

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