CALCIUM CARBONATE SCALE CONTROL IN GEOTHERMAL WELLS

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ABSTRACT

Scaling of wells represents a major problem to many geothermal power plants. Geothermal brines contain dissolved minerals that have a high tendency to precipitate in critical areas. In particular, formation and growth of calcium carbonate scales are harmful to operations by restricting brineflow and causing a decrease in power generating efficiency. Removal of the scale involves taking the well off-line and either physically or chemically removing the deposits downhole. This process restores the well efficiency but is extremely costly and time consuming.

This paper explores the technology behind how polymeric antiscalant additives effectively and economically prevent downhole scale formation and allow uninterrupted efficient power generation. Feeding methods, monitoring techniques and results from major geothermal developers in the U.S resource area will also be discussed. The paper was originally presenfed at one of the GRC conferences.

1.0 Introduction

Calcium-based scale precipitation is a common problem in geothermal fluids and brines. The area most prone to scaling is at the flash point inside geothermal wells. It occurs when the boiling of reservoir fluid and the evolution of CO_2 cause an increase in pH and concentration of calcium and carbonate ions in the liquid phase, resulting in the supersaturation and precipitation of $CaCO_3$ (Lovekin et al, 1990). Reinjection pumps, lines and equipment can also be susceptible to scale formation. An accumulation of these adherent deposits can result in rapid reduction of brine flow, loss of efficiency and eventual interruption of well production or plant operation. Several techniques to control calcite scale have been tried at various geothermal fields including mechanical clean-outs, acid stimulations, and downhole inhibitor injection. Acidizing operations pose a risk of damaging or possibly even destroying a viable production well by attacking the exposed casing and cemented portions of the wellbore. This operation if performed several times per year is uneconomical. To date, the preferred method for scale control in production wells is the use of chemical inhibitors injected downhole to the depth below the brine flashpoints (Robson et al and co workers, 1990).

2.0 Deposition Mechanism

One of the most common causes of scaling in geothermal fluids is the relative insolubility of calcium carbonate due in part to its retrogrative properties. The presence of calcium ions and bicarbonate alkalinity is common in almost every water source.

When the temperature of the water increases, the bicarbonate breaks down to carbonate and combines with calcium by the following reaction:

$$Ca^{+2} + 2HCO_3 \text{ ----> } CaCO_3 + CO_2 + H_2O$$

As the hot brine rises towards the surface in a production well, an equilibrium is reached between 'thehydrostatic pressure and boiling point of the brine causing flashing to occur. The brine at the flashpoint therefore experiences an increase in solids concentration. In addition, carbon dioxide is liberated into the steam phase resulting in an increase in brine pH. These factor drive the equilibrium reaction to the right resulting in the supersaturation and precipitation of calcium carbonate scale formation. The deposition of calcite by this mechanism in the casing of production wells rapidly results in flow restrictions and lost of power production (Benoit et al, 1990).

In the absence of antiscalant reagents, restoring scaled wells back to full production is neither attractive nor economical. It involves taking the well off-line and either chemical or mechanically cleaning the affected area. Mechanical cleaning of the well is both equipment and labor intensive resulting in an uneconomical operation. Moreover, the use of acid is not desirable due to the presence of exposed metal surfaces and cemented portions of the wellbore. Subsequent research conducted by various chemical suppliers under static conditions at expected downhole temperature and pressure has resulted in the development of a series of polymers that had shown promising results in mitigating the problem.

3.0 Treatment Programs

Traditional scale inhibitors act to sequester the calcium cation and prevent it from exhibiting its normal properties. Reagents termed 'threshold" inhibition are used to control large numbers of metal cations at substoichiometric concentrations. Threshold effect inhibitors acting in sub-stoichiometric concentrations can be most effective in controlling calcite formation in challenging environments. Phosphonate-based chemicals have been experimented with some degree of success but has the side effect problems of depositing orthophosphate scales (Benoit et al, 1990). Thermal stability limitations and the corrosive nature of phosphonates has limited their use as downhole scale inhibitor. In recent years, promising polymeric scale inhibition developments has enabled plants to feed these reagents at low dosages and effectively minimize scale formation. More recently, the technology of dealing with calcite inhibition has turned towards polymers with carboxylic or sulfonic functionality. Examples of this would be polyacrylate, polymethacrylate, polymaleic anhydride, sulfonated polystyrene, as well as copolymers or terpolymers .of various types. These compounds mostly act through adsorption on the forming micro crystalline scale nuclei thus preventing their growth to full fledged crystals (Robson et al, 1990),

It has been determined through extensive research and cost comparisons of various polymer types that the optimum molecular weights for polymers used in preventing scale are between 1,000 and 10,000 (see table one). A polymer with too low molecular weight will not function effectively as crystal modifier and loses activity. Polymers with too high molecular weight could cause bridging (flocculation) instead of dispersion (Monette et al, **1991).** ***Other*** factors affecting the efficacy of a polymer on calcite formation are the type and orientation of the functional groups. Today, a properly treated system can now typically function for many months or even years without interruption for cleaning due to calcium carbonate scale.

Table 1. Relation of molecular weight factor to scale reduction efficacy

Polymer	MW	Concentration	Scale Reduction
Polyacrylic Acid	**20,000**	3	**52**
Polyacrylic Acid	**10,000**	3	**61**
Polyacrylic Acid	**5,000**	3	**71**
Polymethacrylic Acid	**10,000**	3	**62**
Polymethacrylic Acid	**5,000**	3	**68**
Polymaleic Anhydride	**10,000**	3	**85**
Polymaleic Anhydride	**5,000**	3	**98**
Polymaleic Anhydride	**5,000**	2	**97**

4.0 Drew 11-498 antiscalant

Drew **11-498** antiscalant, a PMA type polymer chemistry functions by means of a crystal distortion as well as a dispersion mechanism. The polymer which develops negative charges when in water, attaches itself to the growing calcium carbonate micro-crystal causing distortion. This interferes with the ability of the crystal to properly keep growing in a precise geometric pattern. In addition a large negative charge is also imparted on the aborted micro-crystals causing it to repel other like-charged particles (dispersion). The net effect is that very small non-adherent micro-crystals are formed instead of the very much larger adherent crystals present when no antiscalant is used. The treatment program consisted of feeding the chemical (Drew **11-498)** through a six mm. stainless steel capillary tube placed in the wellbore such that the feed point is below the flash point zone.

In formulating an effective maintenance program to combat the problems of scale formation, there are a number of steps that can be taken to optimize this goal. A complete brine analysis, both before and after flashing, including calcium concentration, alkalinity and pH needs to be determined. This information, along with the temperature, pressure of the flash point of the geothermal fluid, helps determine the best treatment approach. A history of well scaling severity from production reports, hole caliper logs and ring gauge runs is also helpful in formulating an effective antiscalant maintenance program.

One of the most difficult aspects of downhole antiscalant treatment is feeding the chemicals through thousands of meters of tubing inside the well. A typical geothermal well head consists of the casing head expansion spool, wing valves, master valves, flowline and crown valve, as depicted in figure 1.

First, the well and wellhead need to be modified to allow the antiscalant to be fed into the well bore 100-125 meters below the lowest encountered scale formation as noted in figure 2. This requires pumping the inhibitor through 1,000-1,500 meters of stainless steel capillary tubing, lowered into the well bore through a lubricator mounted on the well head crown as shown in figure 1. The end of the capillary tubing to be inserted into the well bore has a weight (sinker bar) which is attached to the capillary tubing via a mixing chamber. The purpose of the mixing chamber is to allow the inhibitors to exit the tubing and flow into the well bore where it mixes with geothermal fluid and prevents scaling deposits.

The simplest and most inexpensive method to monitor the effectiveness of the scale inhibitor program is to use the Capillary tubing. This method requires the capillary tubing to be removed from the wells at timely intervals usually 30-90 days and visually inspecting for areas of deposition.

5.0 Case History

Site: Roosevelt Hot Spring - located approximately twelve miles north of Milford, Utah.

Previous Program

This treatment and maintenance program consisted of the following:

i) Acid clean each well three times per year.

Since each acid cleaning incorporated a one day downtime, this cost is also incorporated. In addition, one production well was destroyed beyond repair due to acid attack of the casing.

Total yearly costs: $101,000.00 + replacement well cost of a million dollar.

Present Program

The cost associated with this program include the following:

i) Multiple capillary tubing installations and retractions to ensure that no scale was occurring.
ii) Chemical feed equipment
iii) Feed equipment installation
iv) Chemical costs

Total Costs: $56,900.00

COST COMPARISONS

Previous program: $101,000
Present program: $56,900

Total savings: $44,100.00 + replacement well cost of a million dollar.

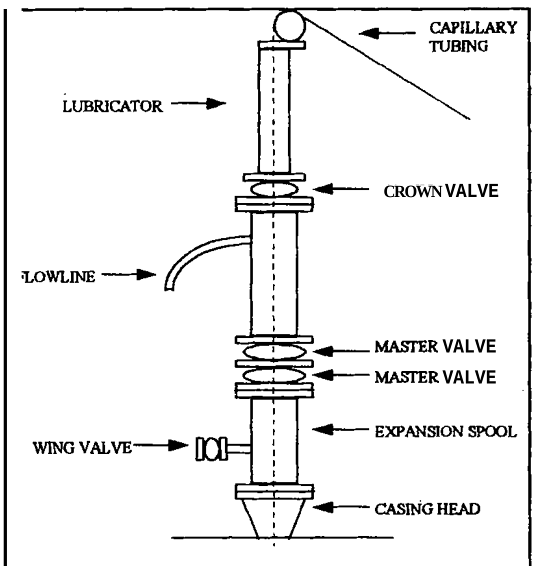

Fig. 1 Geothermal well head

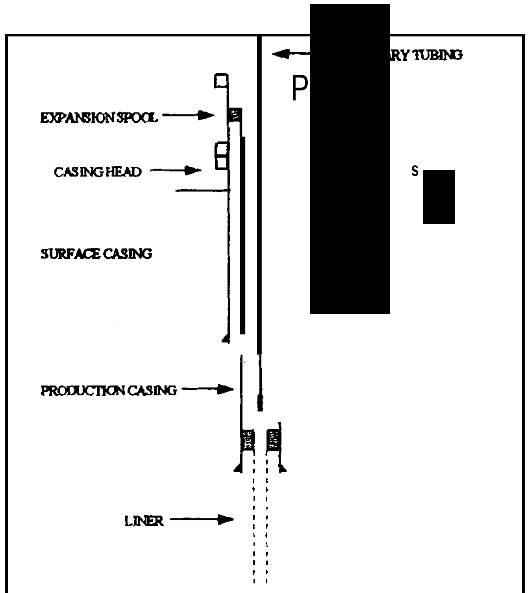

Fig 2. Geothermal well with antisclant feed below flashpoint

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