CHEMICAL TREATMENT PROGRAMS FOR THE PREVENTION OF SALT BLOCKS IN OIL AND GAS PRODUCING WELLS

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ABSTRACT

Many of the oil and gas producing reservoirs produce varying amounts of water, which in many cases can be at or near saturation with respect to sodium chloride salt. If the physical conditions such as, temperature or pressure are changed, the possibilities of salt (sodium chloride) precipitating in the well bore and causing a "salt block" are certainly real.

The mechanisms of this salt block formation vary, but most often it is due to one of two scenarios:

1. Temperature reduction of the fluids as they are transported from the reservoir to the surface. Such cooling decreases the capacity of the water to retain the salt in solution and thereby precipitation of the salt crystals occurs.

2. In the case of gas production, the brine produced is stripped of its water by the gas stream, concentrating the brine solution in the wellbore.

This paper will address the mechanisms, laboratory evaluations of inhibitors, and case histories of well treatments.

LABORATORY INVESTIGATIONS

In the past, most studies on the growth of halite have produces supersaturated solutions by cooling solutions which were saturated at a higher temperature. In other words, a solution was heated to a temperature above the anticipated test temperature and sodium chloride (salt) was added until no more salt was dissolved. The liquid portion was then carefully drawn off and allowed cool to the required temperature.

Another method was to evaporate some of the water from a concentrated brine solution.

In either case the degree of supersaturation is very limited because of the low rate of evaporation that can be achieved relative to the rate of precipitation.

A search of the literature indicated a test based on the work of Frigo *et al* would eliminate most of these objections. This test consisted of mixing a saturated solution of sodium chloride (NaCl) with a solution containing calcium chloride ($CaCl_2$) plus sodium chloride. This enabled relatively large saturations to be obtained essentially instantaneously and isothermally upon mixing.

STATIC EVALUATIONS

The required solutions were prepared and placed in a 190 to 200 ºF (93 ºC) water bath. When the solutions had reached equilibrium the brines were mixed and allowed to stand undisturbed for an additional 30 minutes.

The samples were removed from the water bath, placed on the countertop and observed undisturbed, at periodical intervals for evidence of salt crystal formation. The uninhibited samples usually formed crystals within 2 to 3 minutes.

To evaluate the effect of inhibition, the calculated amount of inhibitor was added to the sample bottle, the brines added and the bottle capped and thoroughly shaken. The samples were allowed to stand in the water bath as above and then removed and observed.

DYNAMIC EVALUATION STUDIES

On one of the more commonly used tests to evaluate scale inhibitor efficiency in the laboratory is the tube-blocking test. Because of the similarities between calcium carbonate and sodium chloride deposition, it was decided investigate this method for the evaluations.

The protocol used in this test was to prepare the two brines as described in the static test procedure and store them in a 190 to 200 ºF (93 ºC) water bath. Using peristaltic pumps the correct ratio of the brines was introduced into a mixing "tee" and then into a five foot (1.5 meter) length of 1/8" stainless steel tubing which was also immersed in the water bath. After leaving the mixing coil the fluids then entered the test coil which was a one meter length of 0.02" i.d. PEEK tubing which was immersed in a 40 ºF (4.5 ºC) cooling bath.

Pressure on the test coil was monitored with a differential pressure transducer and the data collected by a data logger.

As with the scale inhibitor tests, a plot of pressure versus time was made and it was determined a dosage of approximately 50 parts per million (50 ppm) of the inhibitor was required to prevent pressure increased in the test coil. These results compare very favorably with the dosage required in the static tests.

WHY DO SALT BLOCKS FORM ?

Brine leaving the reservoir may be near or at saturation when under the temperature and pressure conditions found in the reservoir. As the brine enters the well bore some pressure is releases resulting in a cooling of the brine. As the brine travels to surface through the tubing to surface additional cooling takes place. As the brine cools, it becomes saturated with respect to sodium chloride (salt) and may precipitate from solution, thus forming a salt bridge or block.

Consider a brine at the bottom of the hole where the temperature is 212 ºF (100 ºC). Under these conditions the solubility of salt is 136 pounds per barrel.

As the brine travels to surface and cools to 86 ºF (30 ºC) the solubility now becomes 125 pounds per barrel. This is a loss of 11 pounds of salt for each barrel of brine produced. Thus 11 pounds of salt can easily precipitate and form a bridge or plug that significantly restrict the flow of both gas and water.

Another mechanism for salt block formation is the concentration of the brine in the bottom of the well.

As water in the lower portion of the well accumulates, gas being produced percolates up through the water and carries some of the water out as water vapor in the gas. This results in less water and consequently more salt in the brine in the bottom of the well. This concentration phenomenon causes the brine to become supersaturated and capable of forming salt bridges or plugs.

FIELD APPLICATIONS

Salt inhibitor applications can easily be adapted to existing well conditions and configurations. Some of the more common ones are:

- As an additive to reduce the amount of fresh water that is required to remove the salt block. This may be with a fresh water dump, continuous fresh water addition down the annular space, or with coiled tubing.
- Reservoir displacements more commonly known as "squeezes"
- In conjunction with fracturing operations.

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CASE HISTORIES

An older gas producing field in the Mid-Continent area of the USA had well which had a low bottom hole pressure. In some cases the wells were being produced using a compressor to draw a vacuum on the wells. Production was 20 to 250 MCF per day of gas with little or no liquid hydrocarbon. Although the water was heavy brine, it was not saturated. A routine of regular fresh water washes was initiated and resulted in production returning to expected rates. Shortly after cleaning, the production fell to unacceptable rates.

Laboratory testing indicated that although the produced water was not saturated with respect to sodium chloride, the gas bubbling through the water in the bottom of the hole carried away enough water vapor to cause the remaining water to become saturated with salt. Eventually salt crystals started to form and the deposits blocked the production.

The well was thoroughly cleaned of salt and other deposits before a continuous treatment of salt inhibitor in fresh water was added down the annulus. The amount of fresh water required was significantly lower that would have been needed in washout jobs.

By eliminating the salt build-up and down time, the well over the past year has increased the average production rate from 31 to 50 MCF per day.

SALT BLOCK INHIBITOR AND HEAVY BRINE FOAMER

Gas wells in East Texas produce gas, heavy brine, and little or no liquid hydrocarbons. Typical production is approximately 500 MCF of gas and 2 to 5 barrels of near saturated brine per day. As production progresses, the heavy brine accumulates in the well bore and rather quickly overcomes the bottom hole pressure, thus "drowning" the well. Secondarily, the gas being produced through the accumulated brine tends to strip water and concentrates the brine. Salt crystals from and eventually form a salt bridge which plugs the well.

The solution to date has been to drop foam sticks when the production decreases. Each time the recovery is less and less effective because of the salt block formation. Frequently coiled tubing was used to "jet" fresh water to remove the salt bridge, however, the well must then be flushed with nitrogen to restore the production.

The inhibitor treatment was made using a capillary string installed inside the production tubing to place the treatment at the bottom of the hole. A mixture of fresh water, salt inhibitor, and a heavy brine foamer was continuously pumped down the capillary.

As a result of this treatment the weekly decreases in production due to water accumulation in the hole have been stopped and no salt blocks have been encountered in over one year.

Before treatment was initiated the average production was 214 MCF per day. After treatment the production for the past year has averaged 524 MCF with 3 barrels of water production.

FRACTURING OPERATIONS

A number of older wells in the Mid-Continent area have very low bottom hole pressures with production in the order of 20 to 250 MCF gas and 2 to 10 barrels water per day. To increase production these wells were routinely foam fractured. Production was increased for only 2 to 3 weeks before salt blocks reduced the gas flow significantly.

A system of introducing the salt inhibitor into the foam frac was designed and initiated. The salt inhibitor was added at two points during the fracturing process. The allowed the inhibitor to be place far enough into the reservoir so a to provide a sustained inhibitor release.

Before the initiation of the fresh water foam/ salt inhibitor fracs, benefits were obtained for two (2) to three (3) weeks. After the treatment benefits have been observed for periods of nine to twelve months. Average gas production has increased from 100 MCF per day to 215 MCF per day.

SAHARA DESERT APPLICATION

Some wells in the desert region of Africa produce from a reservoir that contains gas, oil, and small amounts of saturated brine water. During the normal production cycle, temperature changes cause the sodium chloride to precipitate from solution causing sever salt blocks. Because of the remote location, scheduling equipment, pumps, coil tubing and fresh water, water washes are an expensive and time-consuming operation.

It was recommended that this particular well be treated with salt inhibitor using the reservoir displacement technique or "squeeze" treatment. A spearhead of treated water was injected ahead of the salt inhibitor to condition the reservoir rock. A calculated volume of inhibitor, based on the water production, was injected into the reservoir to a pre-determined depth that would control the feedback rates at a concentration designed to control the salt deposition. Well was shut-in for 24 hours to allow the inhibitor to adsorb onto the rock before resuming production.

Approximately six months after treatment there is no sign of salt build-up and the producer has seen an increase in gas production from 5.6 MMCF to 8.5 MMCH per day and an oil increase from 2598 barrels per day to 4000 barrels per day.

CONCLUSIONS

The results of these treatments have shown that the costs associated with well cleaning to restore production have not only been greatly reduced, but the elimination of the inconsistent producing periods has allowed more overall gas production.

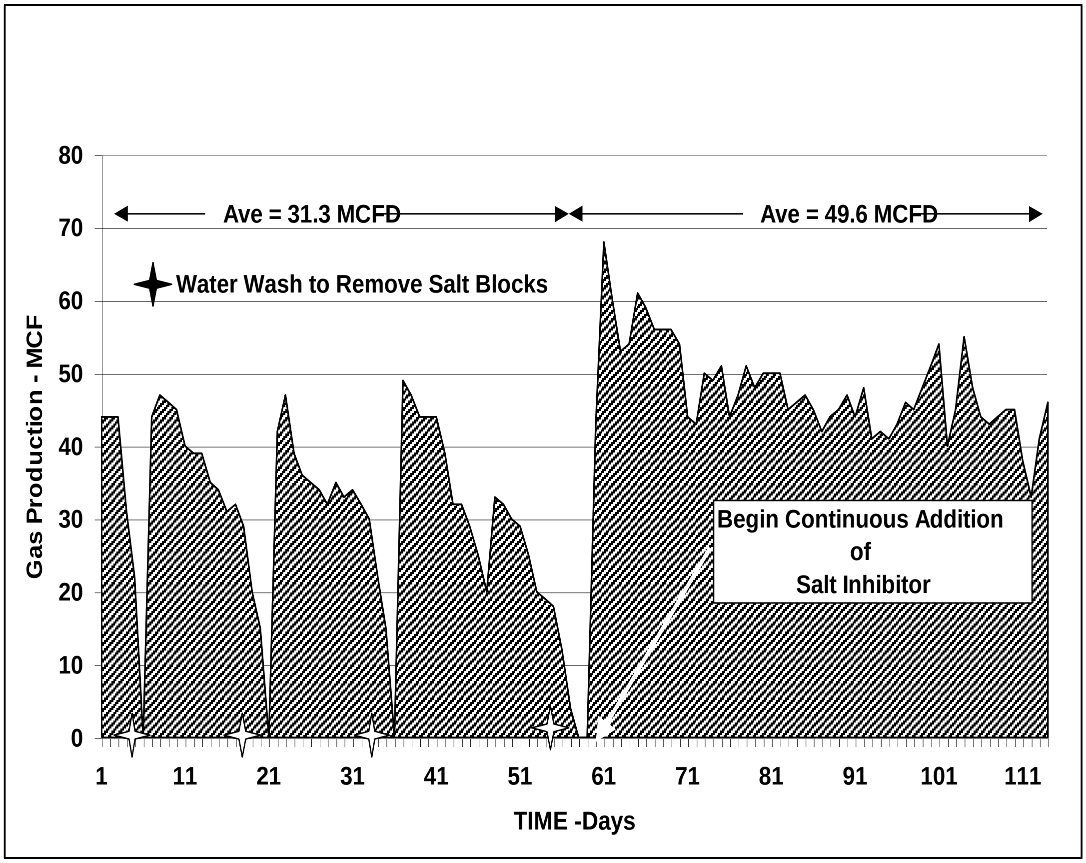

Figure 1 – Production Curves with Continuous Application of Salt Inhibitor

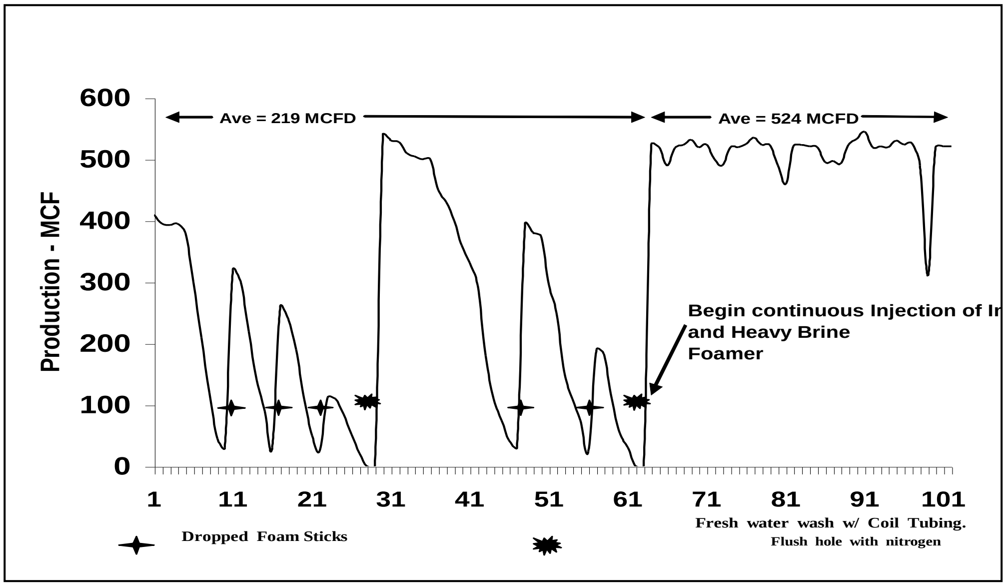

Figure 2 - Continuous Addition of a Salt Block inhibitor and a
Heavy Brine Foamer

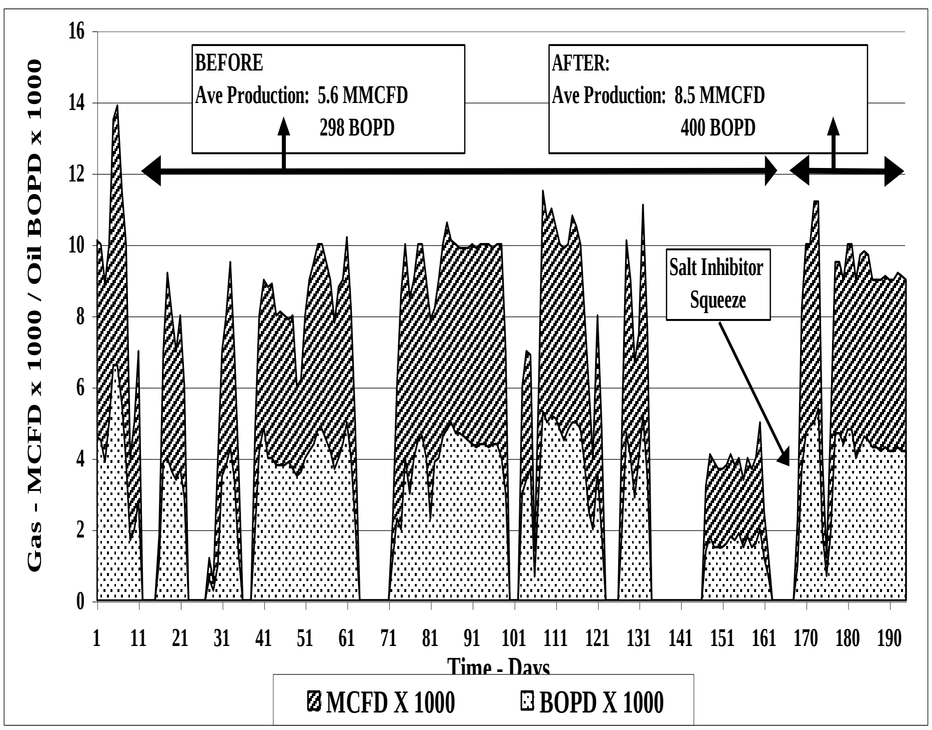

Figure 3 - Fracturing Application with Salt Block Inhibitor

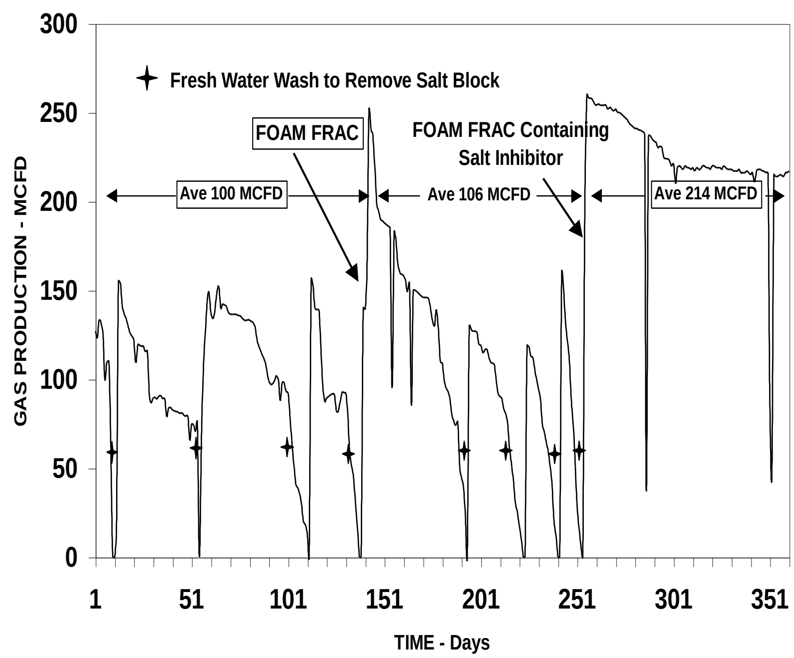

Figure 4 – Sahara Desert Application Well # 1