EVALUATION OF A NEW SCALE CONVERTER/STIMULATION TREATMENT

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INTRODUCTION

The majority of the workovers at the Mabee San Andres Field are for the removal of calcium sulfate scale. The currently used scale converter treatment is a five step process. This includes the application of a paraffin solvent, scale converter, acid and another scale converter followed by a larger acid treatment. A new scale converter treatment is currently being evaluated. This new method uses a xylene-scale converter emulsion as the scale converter and requires only a two step treatment. The well is first treated with the xylene-scale converter emulsion and is then stimulated with acid. The xylene-scale converter treatment has been tested in the laboratory and in the field.

CONCLUSIONS

1. Laboratory tests were made comparing the two treatment methods. Results from the xylene-scale converter treatment exceeded those of the currently used scale converter treatment in the removal of paraffin, calcium sulfate and stratified paraffin-calcium sulfate scale.

2. The xylene-scale converter emulsion treatment results in a 30% reduction in the cost of the workover through savings in pulling unit time, chemical costs, water hauling and miscellaneous time oriented items. There is also less workover associated downtime with this new method.

3. The xylene-scale converter emulsion treatment has been completed on nineteen producing wells in the Mabee San Andres Field with great success. The average production increase for the xylene-scale converter/stimulation treatment is 50 BOPD and 177 BWPD. This compares favorably with the conventional scale converter treatment average production increase of 44 BOPD and 105 BWPD.

RECOMMENDATIONS

1. Continue the field testing of the xylene-scale converter emulsion treatment for the removal of paraffin and calcium

sulfate scale at the Mabee San Andres Field.

2. Monitor the results of the new scale converter method and compare it with those of the currently practiced five step technique.

DISCUSSION

The productivity of the Mabee San Andres Field is severely affected by calcium sulfate scale deposition in both producing and injection wells. Produced San Andres water has a natural tendency for scale deposition. This was confirmed by the Houston Research Center's scale prediction program, Watermix.[1]

Calcium sulfate exists in several forms. These include Gypsum, $CaSO_4 \cdot 2H_2O$, Hemihydrate, $CaSO_4 \cdot 1/2H_2O$ and Anhydrite $CaSO_4$. Gypsum is the most likely form to precipitate up to a temperature of approximately 212 degrees F. Above this temperature Hemihydrate will normally be the form precipitated. This can in turn dehydrate to form Anhydrite. Anhydrite can be directly precipitated above 250 degrees F. Anhydrite can also appear at lower temperatures in an agitated system. Gypsum is the most common form of calcium sulfate found at the Mabee San Andres Field. Calcium sulfate scale deposition is dependent upon its solubility in the system. Decreasing solubility creates an increasing scaling tendency.[2] Some of the factors which influence calcium sulfate solubility are:

1. Concentration of calcium and sulfate ions. Only when these concentrations exceed the solubility limits for calcium sulfate in one of its forms will scale deposition be found.

2. The solubility of calcium sulfate is also dependent upon the salinity. A maximum solubility is reached at approximately 125000 PPM NaCl. The solubility decreases above and below this point.

3. Temperature is a very important factor. The solubility of Gypsum increases with temperature up to 125 degrees F and decreases with further increases in temperature.

4. The presence of the magnesium ion in the salt solution has a direct effect on the solubility.

5. Decreases in pressure causes decreases in the calcium sulfate solubility. Pressure drops can be responsible for deposition of calcium sulfate in producing systems.

The injection water at the Mabee San Andres Field includes both a fresh water and produced water system. This results in a decrease in salinity of the produced water after breakthrough.

At the producing well you have both a decrease in temperature and pressure. All of these factors contribute to the deposition of the calcium sulfate scale.

Given the tendency for scale deposition, the production decline curves are monitored closely for any unusual change in fluid production in individual producing wells. When an unusual change in the decline curve is noted the well is investigated for the possibility of a workover. The majority of the workovers on the producing wells are scale converter treatments. There are three types of chemical converters available in the industry to remove calcium sulfate scale. These include:

1. Inorganic Converters- These react with calcium sulfate to form an acid soluble reaction product.

2. Organic Converters - These react with calcium sulfate to form a water dispersible reaction product.

3. Solvents - These react with calcium sulfate to form a soluble complex with the calcium ion. This product then remains in solution.

The inorganic converting agents used for calcium sulfate removal are the carbonates and hydroxides. With the carbonate systems the calcium sulfate scale is converted to calcium carbonate which is removed by a subsequent acid treatment. The hydroxides convert the calcium sulfate to calcium hydroxide which is soluble in acid. Organic converters such as sodium citrates and potasssium glycolates differ from the inorganic converters in that an acidizing stage is not usually required to remove the reaction precipitate. The reaction products formed tend to slough away from the surfaces to form a water dispersible product. The solvent type treatment differs from the inorganic and organic converters in that an insoluble reaction product is not formed. Solvents or chelating agents remove the calcium sulfate by reaction with the calcium ion. The calcium removed is then held in solution as a stable complex.[3]

The conventional scale converter treatments consist of a five step process. The first step in this process is treatment with a paraffin solvent. The paraffin solvent is spotted across the pay. The bottom of the tubing is pulled above the pay and the packer is set. An additional 110 gallons of paraffin solvent is then squeezed into the formation. The well is then shut in for approximately 24 hours. The residue is swabbed back before going to the second step. The second step consists of the application of 110 gallons of an organic scale converter mixed 1:1 with fresh water. This is pumped in a similar manner to the paraffin solvent. The scale converter is spotted across the pay. The tubing is then pulled above the pay and the packer set. The remaining scale converter is then squeezed into the formation. The well is again shut in for approximately 24 hours. The well is then opened up and the residue is flowed or swabbed back.

This first scale converter softens or removes the calcium sulfate scale in the wellbore or near wellbore area. The third step is to treat the well with 1000 gallons of 28% HCL acid. After 15 minutes shut in the acid load and residue is flowed or swabbed back. The fourth step is to treat the well with 1500 gallons of an inorganic scale converter. This is pumped as before, spotting the scale converter across the pay, pulling the tubing above the pay and setting the packer. This treatment includes diverting with rock salt after one half the scale converter is pumped. This treatment is again allowed to soak for approximately 24 hours. The load and residue is then flowed or swabbed back to the surface. The final step is stimulation with 28% HCL acid. The volume used is 4000 to 8000 gallons depending upon the size of previous treatments. Each successive treatment is designed to extend further into the formation than the previous treatment. This is normally over displaced by 1000 gallons flush containing a nonionic surfactant. After 15 minutes shut in the load and residue is flowed or swabbed back.

In all cases the solvent, converter or acid is circulated to the bottom of the tubing and the by-pass of the packer is then closed. In this manner the tubing volume ahead of the treatment is not bullheaded into the formation, resulting in less load to recover. A spot control valve or hydrostatic control valve is normally used as an aid to control the placement of the treatment. Any volume pumped that is 1000 gallons or greater is diverted with rock salt for optimum distribution. The rock salt is pumped in a cross-linked brine gel because of its superior carrying ability. The conventional scale treatment procedure is listed in Table I.[4,5]

The new method of scale treatment currently being evaluated is a xylene-scale converter emulsion treatment. This new method is a two step process. The first step is to treat the well with 1500 gallons of the xylene-scale converter emulsion. This emulsion, containing an inorganic scale converter, is first spotted across the pay. The tubing is then pulled above the completed interval and the packer set. The remaining xylene-scale converter emulsion is then pumped into the formation. The emulsion is diverted at 750 gallons with rock salt in a crosslinked brine gel utilizing a spot control valve to insure proper placement. This emulsion is allowed to soak for 24 hours. The load and residue is then flowed or swabbed back. The second step is stimulation with 28% HCL acid. The volume used is 4000 to 8000 gallons, again depending upon the size of prior treatments. The acid treatment is diverted with rock salt in a crosslinked brine gel for optimum distribution. The acid is over displaced by 1000 gallons flush containing a nonionic surfactant. After 15 minutes shut in the load and residue is flowed or swabbed back. The xylene-scale converter emulsion treatment procedure is listed in Table II.

There are several advantages to using the xylene-scale converter emulsion treatment versus the conventional scale converter treatment. The xylene-scale converter emulsion has a specific gravity of 1.050 or 8.75 lbs/gallon. This makes it much easier to control the placement of the fluid. Since its specific gravity is similar to the formation and displacement fluids it has a greater tendency to stay where it is spotted. This is critical to insure maximum length of exposure of the treatment to the scale deposits. The paraffin solvent used in the conventional treatment has a specific gravity of .773 or 6.44 lbs/gallon. This makes this solvent very hard to spot or displace. It has a tendency to migrate up because of the large difference in density as compared to the formation and displacement fluids. Evidence of this has been noted during several workovers. After the paraffin solvent was in the well 24 hours the well was opened up to flow back the residue. The first fluid to come back was the paraffin solvent, due to its migration to the top of the fluid column. Some of this has been eliminated by the use of a spot control valve. However, with the low pump rates required to prevent exceeding the fracture gradient, it is believed this migration still occurs. The second advantage of the xylene-scale converter emulsion is that the xylene, which dissolves paraffin and asphaltic deposits, is mixed with the scale converter. This is a very effective treatment for stratified paraffin-calcium sulfate scale. As another layer of paraffin is encountered it is dissolved by the xylene allowing the next layer of calcium sulfate to be converted. This emulsion treatment continues in this manner until the paraffin and calcium sulfate scale are removed or the xylene-scale converter is saturated. For the conventional treatment the scale converter works only until it reaches a paraffin layer. The conventional scale converter will not work on any surface covered by paraffin, oil or an asphaltic deposit. These surfaces must have been cleaned by a solvent.

LABORATORY TESTS

The xylene-scale converter emulsion was also compared to the conventional scale converter treatment in laboratory tests at the Mabee Field Office. These tests simulated a wide variety of problems including paraffin, paraffin coated calcium sulfate scale and paraffin free calcium sulfate scale. The conventional five step scale converter treatment and the xylene-scale converter emulsion treatment were also simulated in the laboratory for comparison of performance. These tests were done at atmospheric pressure and at 500 PSI.

The first comparison was a paraffin test. Three samples of 4 grams of Mabee paraffin were used to test the dissolving capability and dispersibility of a scale converter, paraffin solvent and the xylene-scale converter emulsion. This test lasted 24 hours and was conducted at ambient temperature and pressure. The scale converter did not affect the paraffin in any way. The paraffin solvent currently being used dissolved all the paraffin and made it soft. However all of the paraffin was located in the bottom of the beaker and was not in solution. In downhole conditions the paraffin would have to be hydraulically circulated for removal. Also since the paraffin was not dissolved into the solvent, contact with water could cause the paraffin to reform. The paraffin sample in the xylene-scale converter emulsion was completely dissolved and dispersed in phase with the solvent. In downhole conditions the paraffin should be removed in solution by flowing the well back or swabbing. Because the paraffin is in solution it should not be able to reform.

The second test was the comparison of a paraffin coated calcium sulfate scale in the conventional scale converter and xylene-scale converter emulsion. This test was conducted at 500 PSI and 100 degrees F. After 24 hours the conventional scale converter sample was found in tact with no penetration. No chemical reaction took place. The xylene-scale converter emulsion completely dissolved the paraffin coating and the 6 gram sample of calcium sulfate. This test was conducted at an undersaturation of calcium sulfate scale.

The final test was a comparison of the present workover method to the xylene-scale converter/stimulation treatment. In this test it was assumed all paraffin and oil was removed and had no bearing on the test. This test was conducted at an over saturation to test maximum performance of the scale converters. This test used a 12 gram sample of calcium sulfate scale and was conducted at 100 degree F and 500 PSI to simulate reservoir conditions. The scale sample was left in the conventional organic scale converter for 24 hours. The sample was then washed with fresh water. This sample was then placed in 28% HCL acid. The sample was then washed, dried and weighed. A total of 4.08 grams calcium sulfate was removed. The remaining 7.92 grams were placed in the second scale converter at ambient temperature and pressure. After 24 hours the sample was again acidized in 28% HCL acid. The sample was then washed, dried and weighed. The inorganic converter and acid removed an additional 1.28 grams of calcium sulfate scale. The conventional workover method removed a total of 5.36 grams of calcium sulfate scale. This is a reduction in original scale content of 44.7%. Next, the 12 gram sample was left in the xylene-scale converter emulsion for 24 hours, then removed and washed with fresh water, dried and weighed. The xylene-scale converter emulsion dissolved 4.83 grams of calcium sulfate scale. The remaining 7.17 grams were then placed in 28% HCL acid. The scale was then rinsed with fresh water, dried and weighed. A total of 6.63 grams of calcium sulfate scale was removed by the xylene-scale converter emulsion and acid treatment. This is a reduction in original scale content of 55.3%.[6]

FIELD TESTS

Field tests were also performed comparing the two methods of workover. Two wells which are offsets with similar production history, net pay and structure were used in the field tests. Both of these wells indicated scale deposition from the decline in their production. The wells tested were the J. E. Mabee B NCT-1 No. 8 and 14. Well number 8 was worked over using the xylene-scale converter emulsion treatment. This well was producing 35 BOPD, 35 BWPD prior to the workover and 78 BOPD, 95 BWPD after the workover, for a 122% increase in oil production. Well number 14 was treated by the conventional method. This well was producing 16 BOPD, 96 BWPD prior to the workover and 60 BOPD, 196 BWPD after, for an increase of 275% increase in oil production. Both methods are extremely successful. It was noted that the xylene-scale converter emulsion tended to bring back more fines including iron sulfide and iron carbonate than the conventional workover method.

ECONOMICS

The xylene-scale converter/stimulation treatment results in a 30% reduction in the cost of the workover through savings in pulling unit time, chemical costs, water hauling and miscellaneous time oriented items. A total of 50 hours pulling unit time is required versus the 80 hours for the conventional workover method. The chemical costs of the xylene-scale converter emulsion treatment is approximately $4500 versus over $7000 for the conventional workover. The water hauling expense is reduced as there are less steps and total load to recover. The savings in the miscellaneous time oriented items are the B.O.P., treating packer and labor. There is also less downtime for the well with the xylene-scale converter/stimulation treatment than the conventional workover method. The total cost estimate in October, 1987 of the five step scale converter workover is $31000 as compared to $21000 for the new method.

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Table 1
Conventional Scale Converter Treatment Procedure

1. RUN BIT TO T.D. TO CLEAN OUT HOLE. IF OPEN HOLE RUN JET WASH TOOL.
2. PUMP 4 DRUMS OF PARAFFIN SOLVENT.
3. SHUT IN FOR 24 HOURS
4. FLOW OR SWAB BACK LOAD AND RESIDUE TO PIT.
5. PUMP 2 DRUMS OF ORGANIC SCALE CONVERTER, DILUTED 1:1 WITH FRESH WATER.
6. SHUT IN FOR 24 HOURS
7. FLOW OR SWAB BACK LOAD AND RESIDUE TO PIT.
8. PUMP 1000 GALLONS 28% HCL ACID
9. AFTER 15 MINUTES, FLOW OR SWAB BACK LOAD AND RESIDUE TO PIT.
10. PUMP 1500 GALLONS INORGANIC SCALE CONVERTER.
11. SHUT IN FOR 24 HOURS.
12. FLOW OR SWAB BACK LOAD AND RESIDUE TO PIT.
13. STIMULATE WITH 4000 TO 8000 GALLONS 28% HCL ACID.
14. FLOW OR SWAB BACK LOAD AND RESIDUE TO PIT.
15. RETURN WELL TO PRODUCTION, CLEAN UP LOCATION.

Table 2
Xylene-Scale Converter/Stimulation Treatment

1. RUN BIT TO T.D. TO CLEAN OUT HOLE. IF OPEN HOLE RUN JET WASH TOOL.
2. PUMP 1500 GALLONS XYLENE-SCALE CONVERTER EMULSION.
3. SHUT IN FOR 24 HOURS.
4. FLOW OR SWAB BACK LOAD AND RESIDUE TO SURFACE.
5. STIMULATE WITH 4000 TO 8000 GALLONS 28% HCL ACID.
6. FLOW OR SWAB BACK LOAD AND RESIDUE TO PIT.
7. RETURN WELL TO PRODUCTION, CLEAN UP LOCATION.