Scale Removal & Prevention In Petroleum Production

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INTRODUCTION

Scaling of oil wells, injection wells, equipment and flow lines is a serious production problem. The scales, which are formed from the produced brine, may be one of many chemical compounds or a mixture of several. The effect of scale deposits can be noticed in many ways, but all are factors which will show up in the economics of production.

Deposits from produced water have been found in almost every part of a production system from the producing formation to the formation face of disposal and injection wells.[1,2] These deposits could result in rapid production decline, broken rods and equipment, damage to pumps and plugging of lines. The rapid decline could result from plugging of perforations, formation face in open hole production or the true or fracture permeability of the formation.

The chemical composition of scales can vary as much as the location of the deposits. Mineral composition depends on the mineral content of the produced brine and the conditions under which it forms. It can be a very pure material or a mixture of several compounds and even have sand or other formation fines trapped in the scale. Some of the most common scale deposits are calcium carbonate, calcium sulfate, barium sulfate and iron compounds. The physical appearance of the deposits may be quite different even though chemically similar.

An example would be the different calcium sulfate deposits that have been found in wells. Some of the crystals recovered have been up to three inches long while other deposits did not appear crystalline without magnification. Most of the deposits fall in between, with crystal structures about one-half inch long. Scales have been found in wells in the shape of little balls which, even though they were not attached to the equipment in the well, caused considerable trouble. Many wells have become plugged with common salt or other water soluble salts due to crystallizing from the strong brine being produced.

Scale can be deposited in wells due to a great many causes. Possibly the most important are changes in pressure and temperature, evaporation, and mixing of incompatible waters. These changes can result in the solubility of the precipitating compounds being exceeded, thus forming a scale deposit.[2,3]

IDENTIFICATION OF SCALES

Identification of scales is necessary to select the proper removal technique. This identification may only need be a rough grouping that can be accomplished without the necessity of a laboratory. Other times a complete laboratory analysis may be desirable, especially when the scale does not respond to the more common means of removal.

Field indentification will seldom track down the exact compound or compounds present in a scale, but this is not always necessary. In many cases a test to group the scale into acid soluble or acid insoluble will be the only identification necessary. Water soluble deposits can also be handled in the field as the compound identification is usually not necessary for their removal.

If the scale is acid soluble, i.e., dissolves or completely breaks up in acid, then some kind of acid treatment will probably be used in removal. If the scale is not acid soluble, or if it is a scale on which acid does not seem too effective, then a laboratory analysis would probably be advisable.

In the laboratory there are several methods available to determine the chemical contents of a scale. Of these, X-ray analysis is usually the best and fastest approach due to the small quantity of sample required and the speed of the determination. X-ray analysis will usually give the exact chemical compounds present and an estimate of the quantity in the sample.

The exact percentage of any specific scale component is usually not too important and further analysis is unnecessary. Sometimes crystallography is used in this type of identification when X-ray is not available since it can also give the exact chemical compound but not the percentage. When the exact percentage is desired or when the material is a common type of scale, regular wet analysis will be all that is necessary.

Another method that has found rather wide use is to dissolve the scale and use a flame spectrophotometer to obtain an elemental metal analysis. On some unusual scales it may be necessary to use several methods before the sample is completely identified.

SCALE REMOVAL

When the scale has been identified, whether by field methods or laboratory analysis, the selection of a means of removal is necessary. There are many methods by which scale can be removed from a well or equipment but usually a scale that is acid soluble will be removed by using a hydrochloric acid solution. This, in itself, is not a simple selection since there are many conditions to consider and additives available that can be used to assist in the special condition or problem.

Sometimes the scale will be so covered with paraffin deposits as to make the scale removal virtually impossible without some treatment to take care of the paraffin. This could be a hot oil treatment prior to scale removal or the use of a special paraffin solvent. Sometimes it has been found very effective to use a hot acid treatment in which the acid is reacted with magnesium or aluminum in the well bore to heat up the entire system. In other cases the paraffin problem may not be serious enough to warrant a special treatment; a surfactant in the acid to assist in the penetration of the scale will be all that is necessary to get an effective scale removal treatment.

Injection wells also need special consideration for removal of scale since there is a possibility of clays, fines and oil getting into the system and depositing on the face of the formation. A detergent wash is sometimes used to remove this type of containment before a scale removal treatment. The solution can be placed in the well and allowed to soak or it can be circulated to get agitation. Either way, it is desirable to allow the solution to flow back or be swabbed back before a scale removal treatment. This will help keep the removal materials from being pushed farther back into the formation.

Iron is perhaps the most common problem encountered in acid removal of scales. Most spent acids contain dissolved iron compounds, the concentration of which will vary considerably due to the type of scale removed and the condition of metal goods in the well. Additives are available which are designed to control the precipitation of the iron when the acid becomes spent.

The length of time that is necessary to control this re-precipitation is the factor to consider when choosing an iron retention additive. Some will control very well for a short time and others will control it almost indefinitely. But, of course, cost should be considered. In any specific treatment, cost and control time should be balanced and the best treatment selected to fit the specific conditions.

Other Problems Encountered

Many other problems are encountered in removal of scales by acidizing and one more should be mentioned, if for no other reason than to stress the possible danger of its removal. This scale is iron sulfide and, although not difficult to remove, it has the added problem of producing a poisonous gas. This gas, hydrogen sulfide, is evolved in the reaction of hydrochloric acid on iron sulfide and proper precaution should be taken any time this type of scale is suspected.

Until recently, scales other than acid soluble deposits had to be removed mechanically. Now, one of the acid insoluble scales can be removed chemically. Calcium sulfate, or gyp, probably the most common of the acid insoluble scales can be removed by chemical means. Since the chemical removal is specific for calcium sulfate scale, it is necessary to determine what type of scale is present. The process is economical, since it removes the gyp scale without the necessity of removing downhole well equipment.

The chemical treatment for removal of calcium sulfate scale is slow in comparison with the removal of acid soluble scales. It is accomplished by two easy chemical steps.

The first step is a treatment with a chemical solution which converts the acid insoluble calcium sulfate scale into an adhering acid soluble scale. The adhering characteristics are helpful as they tend to keep the scale from breaking up and falling to the bottom of the hole. The first step is the time consuming part of the treatment as the solution is usually allowed to stand in contact with the calcium sulfate scale for 24 hours. The solution is then pumped out of the well and the second step undertaken.

The second step is much the same as removing any acid soluble scale, being a treatment with inhibited hydrochloric acid containing a surface tension reducer and non-emulsifiers if necessary. After the acid has been given sufficient time to react, as in any normal acidizing job, the solution is pumped out and well operation resumed.

With other acid insoluble scales, such as barium sulfate and strontium sulfate, it is still necessary to resort to mechanical means of removal.

MECHANICAL MEANS OF REMOVAL

Of the mechanical means of removal, besides the normal washover or pulling and milling operation, there are two methods that are becoming better known and could be considered for their merits in any scale removal operation.

One of the methods utilizes a series of small explosive charges set off at predetermined intervals to set up a series of shock waves. The charges are designed to cause contraction and expansion of gas bubbles which remove or shake off the scale deposits. The charges are of sufficient power so that scale will be removed but small enough to minimize that possibility of damage to the casing. This method of treatment was first used in the redevelopment of water wells that had lost production due to scaling, but has been used very successfully in treating producing oil wells.

The other method, that has again come into use, is the jetting of fluids containing abrasive materials to grind or knock off the scale much as sand blasting will do. The treatment was initially designed to utilize acid more efficiently in a restricted space.

More recently, tools have been designed to perforate pipe and cut into formations prior to fracturing. These tools have also been very successful in removing scale from plugged injection wells. Most of the removal treatments have been done in open hole completions but could be used in cased wells if precautions were taken so that the tool would not remain in one place long enough to cut the casing.

Mechanical means of removal are, of course, suitable for any type of scale that might be present and the only limitations would be the conditions that exist in a particular well.

SCALE CONTROL

Scale control is perhaps the most important part of a scale removal and control program, since if a sound scale control treatment is not selected the scale removal treatment might have been wasted. Usually, a scale control method is more economical than periodic removal treatments.

There are several general methods that might be followed to outline a scale control plan and many materials that could be used under each plan. For the purpose of this paper, we will consider only some of the chemical means of treating a producing well and not delve into the so-called "Water-Conditioning Gadgets" or water conditioning for injection.[4]

The first type of treatment that was used followed the methods used on normal industrial water treating systems of dissolving chemicals in water or produced brine and bleeding them down the well. This system is still in very wide use and extremely effective in a number of cases. The system, of course, has limitations as to the arrangement of downhole equipment and pressures encountered, not to mention weather conditions and labor costs.

The chemicals that are being used in this type of treatment are numerous; some are surfactants while the majority are complex phosphates of one type or another. There have been many types of materials and equipment developed for this type of treatment since other methods of treatment were impossible until a very few years ago.

Another type of treatment was probably a direct outgrowth of the development of a group of complex polyphosphates that had the property of dissolving very slowly in water or brine. This development allowed the materials to be dumped down the hole in solid form, thus giving continuous feed without the need of special equipment. Another way these materials are being used is in bypass feeders, which need very little attention, with the treated solution being bled back down the well.

These methods of downhole treatments are being used very successfully; but it has been found that, in some instances, the treatment simply did not control the scale at the points most necessary for continued economical production. These treatments help protect the well from scaling from the well bore on out the hole but are not effective within the formation, fractures or perforations.

Side wall cores have been taken from wells where the permeability had been damaged by scale deposits. This, of course, could adversely affect the productivity of a well and there are many wells that have too rapid a decline for the pressures and other reservoir conditions. Many of these rapid production declines might well be caused from scale deposits.

Newest Method

The newest method of treatment is designed to control the deposition of scale from the time the brine leaves the actual formation and enters a fracture or well bore. In this type of treatment, slowly soluble complex phosphates, which have been developed for this special use, are mixed with fracturing sand. When the well is fractured, the mixture of sand and chemical is placed in the induced fracture. This method of placement gets the material in contact with the brine to be produced at the most critical points of the production system.[5] Thus, the treatment begins in the fracture and continues throughout the well.[6,7]

The solubility of these materials vary with temperature and the brine concentration. The length of the life of a treatment of this kind will depend on the solubility of the phosphate along with other factors. The selection of a material and amount to be used should take into consideration the bottom hole temperature of the well if long-lasting, effective treatment is to be accomplished. Wells treated in this way have had successful scale control periods from six months to over a year.

A well in west Texas treated with 200 lbs. of phosphate over three years ago still has no scale problem. The pump was recently pulled for inspection and no scale was observed. An offset well not treated has had very serious scaling trouble. Until recently the materials had temperature limitations due to solubility and other factors which would eliminate their usage as the bottom hole temperatures approached 200° F. A new material has now been developed which will increase the top limit for this type of treatment from 200° F. to 260° F. With this new material it will be possible to give a combination fracturing and scale control treatment to virtually all scaling wells that are now encountered.

SUMMARY

The importance of scale control is becoming increasingly critical in economic oil production. Scaling conditions require a three-step procedure to fully understand and cope with the problem. These are identification, removal and control — with control probably being the most important. The same type of removal and control treatments will not be the same for all wells, but the specific condition of each well should be taken into consideration.

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