OIL & GAS WELLS DOWN HOLE DEPOSIT BUILD-UP DEPOSITION MECHANISM REVIEW REMOVAL AND INHIBITION USING THE MAG-WELL MAGNETIC FLUID CONDITIONER (MFC)

Hector Partidas

Introduction

One of the most difficult and profit hurting problems found in the oil field is the build-up of deposits in the well bore, production string, flow lines and even in storage tanks. These deposits act as a restriction during build-up in the wellbore causing a gradual decrease in production and, in many cases, as a solid barrier for wellbore fluid flow. Unless remedial action is taken, this blockage may cause rod failures, tubing leakage and damaged pump parts plus lost production.

Over the years such remedial actions cost the Oil Industry Millions of dollars. Unfortunately, conventional treatment methods, either mechanical or chemical, are mostly focused in fighting the effects yet not the causes.

A third method based in an applied magnetic field is being used for effective removal and inhibition of both organic and inorganic deposits. By flowing well fluids through a strong magnetic field inside a housing the deposition pattern is altered without affecting the crude oil characteristics.

In this paper the deposition mechanism of both inorganic and organic deposits is reviewed and the use of the Magnetic Fluid Conditioner manufactured by Mag-Well, Inc, a Dallas based company is discussed.

General

Deposits are either organic or inorganic. Inorganic deposits are mainly compounds such as Calcium Sulfate, Calcium Carbonate and Barium Sulfate being usually referred to as mineral scale or simply scale. Organic deposits, on the other hand can be either in the form of paraffin or asphaltene compounds.

DEPOSITION OF INORGANIC DEPOSITS

(SCALE)

Deposition Mechanism

Deposition of scale from brine or connate water produced with oil is a common problem in many producing, injection and waste disposal wells.

Scaling takes place when the equilibrium of the brine is altered by changes in the state of the well fluids or by mixing incompatible waters caused by the drilling and production activities.

Before these activities take place, well fluids in the reservoir remain in a state of equilibrium. As the well is drilled and production starts, the pressure drop causes dissolved gases to come out of crude oil and destroys this equilibrium. This change causes deposits to form. Water from different zones may become mixed in the wellbore or injection water may mix with formation water. Incompatibility may result when one water contains a high concentration of calcium or barium and the other contains a high concentration of sulfate or carbonate ions in crude oil. As these waters mix, the resulting crude oil becomes saturated with calcium sulfate, barium sulfate or calcium carbonate and deposition occurs.

The deposition mechanism is mainly responsible for the physical properties of scale. A rapid deposition pattern will yield soft scales while a slower deposition pattern will form a hard and dense scale making it harder to remove.

As a whole, physical form of scale can be grouped into three categories: thin, laminated and crystalline. Thin scale is the most permeable and easy to remove while laminated and crystalline scale are less permeable hence harder to remove.

Factors affecting deposition

Factors such as pressure drops, temperature changes, supersaturation, contact time, pH and the mixing or water can result in severe scaling problems. Formation of scale, however, is not normally caused by the action of a single factor nor the cause is common to the different types of scale. As changes in the equilibrium take place, interaction of these changes with other down-hole conditions play an important role on the deposition mechanism which will affect the final form of scale. This, in turn, has a significant effect on the method chosen to remove the scale.

DEPOSITION OF ORGANIC DEPOSITS

(PARAFFIN AND ASPHALTENE)

The chemistry of petroleum is a part of organic chemistry, which deals essentially with carbon compounds. About half a million different compounds of carbon have been found being the simplest those that contain only carbon and hydrogen, known as hydrocarbons.

Hydrocarbons have been divided into various series, differing in chemical properties. The four that comprise most of the petroleum's are: the normal paraffin (alkanes), the isoparaffin (branched-chain paraffins), the naphthene (cycloparaffin) and the aromatic (benzene) series. Crude oils are referred to according to their relative richness in hydrocarbons of these groups, as paraffinic-base, naphthenic-base or mixed-base (naphthenic-paraffinic) oils.

Paraffin

(Alkane) Series. They are saturated, straight-chain (aliphatic) compounds. By large, they are the most abundant hydrocarbons present in both gaseous and liquid petroleums.

All the members below pentane are gaseous at ordinary temperatures while those between pentane and pentadecane are liquid. The higher members are waxy solids.

Naphthene (Cycloparaffin)

Series. These are saturated, closed-ring compounds having the general composition. Naphthenes resemble the paraffins in both physical and chemical characteristics but are more stable. Cyclopropane and methylcyclopropane are gases at ordinary temperatures and pressures. All the other members of the monocyclic naphthene series are liquid the most abundant being cyclopentane and cyclohexane (061112). Crude oils with high percentage of naphthenic members are also called "asphalt-base crudes" for the many complex asphaltic members from the higher boiling point ranges.

Paraffin Deposition Mechanism.

Even a slight change in the equilibrium conditions results in the deposition of an amorphous and microcrystalline waxy material known as paraffin. Consistency of the deposit will vary from soft to hard and brittle. The higher the molecular weight of the materials forming the deposit, the harder and difficult becomes to remove it.

Paraffin is normally deposited in the wellbore extending up the production string and even in flow lines and storage tanks as a result of the cooling of the oil rising to the surface and flowing to the flow station. Paraffin wax may also precipitate and clog the pores at the face of the reservoir when the expanding gas cools as it enters the wellbore.

Loss in solubility as a result from changing the crude oil equilibrium conditions is the trigger for paraffin deposition. Temperature and pressure changes, evaporation and loss of dissolved gases are the main causes for altering the crude oil equilibrium.

Paraffins having the highest molecular weight and melting point are the first to separate from crude oil, that is, are less soluble. This mean that the solubility of paraffin waxes in a specific crude oil at a given temperature decreases with an increase in molecular weight and melting point.

Factors Affecting Paraffin Deposition

Temperature.
As stated above, loss in solubility of paraffin in the crude oil is the trigger, for deposition. One of the main causes for this loss in solubility is the temperature changes in the liquid.

Most of the temperature changes in the crude oil are the result of the cooling action produced by:

1. - heat radiation to the surroundings at it flows from bottom to surface

2. - gas lifting

3. - liberation dissolved gases

4. - vaporization of lighter petroleum fractions

5. - water injection

6. - Formation Orifice Effect (FOE).

No matter what the operator does to the oil, if the temperature of the crude oil reaches its Cloud Point, the paraffin will start precipitating.

If the temperature continues to go down the small wax crystals begin an interlocking action until the crude oil will stop flowing. This temperature is known as the Pour Point. In summary, the higher the Cloud and Pour points are, the less able the crude oil is to keep the paraffin soluble.

Pressure.
Pressure has a direct effect on the solubility of the crude oil. It will keep the gas and the higher petroleum fractions in crude oil. However, to produce the well, it is necessary to have a pressure drop or drawdown. The higher the drawdown, the larger the cooling of the crude oil which normally takes place right at the formation face. Here, the tiny fluid passages in the formation act as orifices originating expansion of the gas followed by vaporization of the lighter components as the oil leaves the formation and enters the wellbore. This will cause the crude oil to cool down hence the solubility of the paraffin in the crude oil is lowered too.

Another important effect of the loss of lighter components that is seen in old fields. As the field becomes older, the lighter components are constantly being removed from the crude oil even within the formation.

This action saturates the oil with paraffin even before it leaves the formation since the paraffin is more soluble in the lighter components of the crude oil than in the heavier ones. This is why, paraffin deposition is more severe the older the field becomes.

Formation Fines.
Formation fines such as sand and silt often act as a nucleus for the cohesion of the small wax particles suspended in the oil into larger particles. This will make the particles larger which will tend to separate more easily from the oil.

Asphaltene Deposition Mechanism.
Asphaltenes are colloidal solutions, highly dispersed and stable. Asphaltene deposits are usually very hard and brittle hence making its removal more difficult. They are insoluble in petroleum naphthas but soluble in polar solvents like piridine, nitrobenzene, benzol, etc. Instead of melting when heated, they swell and decompose into coke-like material. Their apparent molecular weights are on the order of several thousand and their chemistry and molecular structure are indefinite. A typical analysis show the following approximate composition: C: 85.2; H: 7.4; S: 0.7 and 0: 6.7 percent. Asphaltenes are the major constituents of the solid bitumen gilsonite.

When the solution loses its ability to disperse the colloidally suspended solid particles asphaltene deposition takes place down-hole at wellbore and adjacent to the pay zone. In extreme circumstances, as in some fields in East Venezuela, the deposits can severely plug off the production string, wellhead and even flow lines.

Factors Affecting Asphaltene Deposition
The balance tending to hold the asphaltene in a stable suspension is susceptible to most of the same conditions causing paraffin deposition plus the composition of crude oil and the nature of the reservoir rock surface.

Magnetic Fluid Conditioners have been in use for some time to treat both inorganic and organic deposition in oil wells, cooling towers and other industrial complexes. The basics for the MFC's in use in the oil industry is that by flowing well fluids through a strong magnetic field inside a housing the deposition pattern is altered without affecting the crude oil characteristics thus inhibiting the build up of solids in the well and production equipment.

There are three main components in a MFC: 1) The case or housing, 2) the magnetic material used and 3) the circuit design. The case or housing is where the permanent magnets are attached. The best material available so far is the series 300 stainless steel due to the tough conditions found in an oil well. The magnetic material is one of the most important components of the MFC since it will generate the magnetic flux which will act on the fluid passing through the tool.

Magnetic materials can be classified in a) soft non-retentive and b) hard retentive. The second group is the one most used today in MFC's since they yield higher energy product along with high remanence and coercitive force which make them ideal for permanent magnets.

The energy product (BH) is an indication of the magnetic energy available outside the magnet and the higher it is, the higher the flux density acting on the passing fluid.

Along the years the progressive increase in the availability of higher energy product magnetic materials have enhanced the possibility for the designing of more powerful MFC's. This means that today's MFC's are 1.5 to 2 times stronger than 2 years ago as the new rare earth magnetic material whose energy product is in the range of 30-40 MG-Oes. However, no matter the power of the magnet and the quality of the housing to hold it, the tool will no work properly if the circuit design is not the appropriate one.

Gruber and Carda (South Dakota School of Mines) proposed grouping the basic design of magnetic devices into four classes:

Class 1. - This design consist of magnets, usually made of ceramics material, fastened to the outside of a pipe, sometimes short lengths of production tubing (pup joints), so the device can be screwed into the production string. This is the first generation design. It is the least likely to succeed because the magnetic energy is first absorbed by the steel case. The remaining energy acts mostly parallel to the fluid flow and the central mass of the fluid is not exposed to the magnetic energy. This is why most of the time multiple tools need to be placed in the production string. Because the magnetic energy also acts outside the tool, well logging is likely to be affected. Class II. - This type of device makes provision to control the direction of flux (perpendicular to the fluid flow) and to compress the flux to increase its density in the fluid passage. The fluid is exposed in its entirety to the magnetic flux which assures that, in normal producing conditions, one tool is enough to treat the production of a given well. The permanent magnetic material does not give up its strength to the system so production well logs are not affected.

Improvements to this design by Mag-Well, Inc, have turned into the Second MFC Generation. No external power is required at all and there is no need to regenerate the internal magnets. The energy source comes from a slight pressure drop, which occurs when the fluid passes through the venturi inside the tool.

Class III. - This design consists of a magnet or series of magnets suspended as a core in the center of
a ferromagnetic tube or pipe. The magnets are usually set longitudinally with closed packed opposing poles.

As for Type I design, here the portion of exposed fluid to possibility to compress flux density does not exist. This makes this design inefficient and would also need multiple tools to yield moderate results. Class IV. - This class contains some electromagnetic types, which are not practical in oil wells.

Mag-Well Magnetic Fluids Conditioners. The Second Generation.

Design.
The basics of the MFC requires well conditions that fit into scope of the design. If the MFC is not properly designed for a particular well, it will not be fully efficient. The scope of the design comprise many parameters being the following the most relevant:

a) Flux density, direction and strength of the magnetic field. b) MFC internal velocity of the fluid being treated and c) Exposure time of the fluid to the magnetic flux inside the MFC.

Type H design is the only one able to allow a complete control on both density and direction of the magnetic field. With this in mind, Mag-Well, Inc has developed the Second Generation of MFC's. Through a careful design based on the production rate, the MFC is designed to achieve a perfect balance between the magnetic field density and intensity and the velocity and exposure time of the fluid to be treated.

Producing mechanism is extremely important for the design of the MFC. For natural flow or continuous gaslift wells the internal flow area is one of the major parameters since it will control the velocity of the fluid inside the MFC

The balance must be exact to achieve the right exposure time with the minimal pressure loss (needed to energize the permanent magnets) through the MFC. This guarantees that the flow area inside the MFC will not impose a restriction to the flow of fluids from the well.

For reciprocal pumping or intermittent gaslift wells considerations are mainly based on the amount of fluid entering to the tubing string on each cycle. Critical parameters are the pump plunger diameter; stroke length and strokes per minute for pumping wells. For intermittent gaslift cycles per hour and amount of fluid per cycle are important design parameters.

For wells producing through ESP or PCP the design criteria is more like the one for natural flow or continuous gaslift wells.

Depth of deposition is critical for the correct placing of the MFC in the tubing string.

Formation temperature is also essential since it will dictate the type of material to be used for the permanent magnets and the rest of the components.

Based on the foregoing, it is necessary to collect the best set of data from the well to be treated so the MFC will be designed for those particular conditions. Gaslifted wells generate additional cooling of the fluid in front of the gaslift mandrels so the collection of data here is even more important. One of the common mistakes some operators make is to believe that if the MFC was efficient in well 'A' it will also be in well B'. The truth is that unless both wells falls within the same designing scope, chances are that it will not work with the same efficiency in the second well. There is an exception, however. In Maraven's La Concepcion field, the MFC from well C-211 designed for 50 bpd, was installed in Feb 1994 in well C-200, a 25 bpd well with several rig jobs for paraffin deposition. During the remaining of 1994 the well produced without paraffin problems.

The MFC can treat either organic or inorganic deposits by changing only the exposure time of the fluid provided that the characteristics of the wells are similar.

Placing the MFC.
Depending upon the amount of fluid passing through the MFC and the completion of the well, Mag-Well manufactures two types: Insert (1) and Tubing (T). For each type there are four series to match the tubing size: Series 300 for 2-3/8", 500 for 2-7/8", 700 for 3-1/2" and 1000 for 4-1/2" tubing.

The insert type has the advantage of placing it without manipulating the tubing. The 300 series can handle up to 750 bpd of fluid passing through the MFC, the 500 up to 1500 and the 700 series up to 3500.

In natural flow or gaslift wells, the insert type is run with wireline and set in the seating nipples of the production string.

In sucker rod pumping wells, the MFC is installed below the pump by only running it with the sucker rods.

The Tubing type is made up in the tubing string and its use is recommended when production rate exceeds the insert type capacity or those wells with ESP or PCP pumps. However, depending on the completion, insert types can be installed on wells with these types of submersible pumps.

MFC Life.
The life of the tool is not known yet since some of the first of the 1000+ installed around the world are still in the wells. Mag-Well guarantees 7 years. It is believed that it could be between

10 and 12 years.

Experiences in Venezuela.
3 MFC's were installed in June 1992 for Maraven in La Concepcion, a field well known for its paraffin problems. Engineering Report IT-11269.93 dated May 1993 reported satisfactory results after 9 months of evaluation and recommended to install the MFC in more wells. In that period it was calculated that annual savings were in the order of US$ 40,000 in equipment and US$ 150,000 in production recovered. On the enclosed graphs one of the wells, C-211 was taken as example for comparison.

Advantages:
a) Remove and inhibit deposition b) Neither external power nor maintenance needed c) 100% safe for personnel, equipment and environment d) Rig needed only for installation in pumping wells or with the tubing type. For natural flowing or gaslift wells the tool is set with wireline. e) Cost effective and Long Service Life. f) Can protect equipment from bottom hole up to tank farm storage g) Well logging not affected.

Disadvantage:
a) Not a Full Bore tool when the Tubing Model is used.

References:
Corney. John. "Advancements in the Use of Magnetics for Controlling Deposits and BS&W in Oil Wells", 1993 Short Course, Texas Tech University, Short Course, Lubbock, TX Vera. Tarquino: Lopez. Antonio and Nunez Jose. "Evaluacion del Acondicionador Magnetico de Fluidos para Controlar la Depositacion de Parafina en La Concepcion", Technical Report No. IT-11269.93, Maraven, May 1993.

Maracaibo, October 1994.