FIELD RESULTS FROM THE USE OF A UNIQUE PHYSICAL FLUID TREATMENT DEVICE TO CONTROL SCALE AND PARAFFIN IN OIL AND GAS WELLS

Wiley Parker, Lawrence Rzeznik and Mario Ledesma, Weatherford International
Thomas Price and Shawn Young, Henry Petroleum LP

ABSTRACT

Scale and paraffin problems cost the oil industry billions of dollars in prevention, maintenance and repair each year. A new and innovative approach to well management, using a physical fluid treatment device, will be presented showing how it reduces well interventions and, correspondingly, improves production efficiency. Over 45 wells in West Texas were treated for scale and paraffin using a unique physical fluid treatment device over a period of 24 months. Specific case histories will be highlighted identifying prior operating issues and comparing favorable use incorporating the physical fluid device. The device, operating at 120 khz, is conveniently attached at the surface of the well and causes the scale to nucleate in the produced fluid rather than on the walls of the well tubulars. Paraffin is attracted to the scale and other inorganics and also remains in the produced fluid. Paraffin and scale are carried away with the produced fluids.

INTRODUCTION

This paper describes the use of a physical treatment program and its affect on the maintenance schedule required by a series of West Texas oil wells. The wells affected were struggling with persistent and prolific scale and paraffin deposition on the tubing on rods.

Deposit formation in wellbore tubing and components is among the more widespread problems in the oilfield. Deposition of paraffin and inorganic scales is a serious problem in many wells in the Permian Basin. Production problems associated with inorganic scales are primarily the result of their formation on pipe and heat transfer surfaces. These deposits are not restricted to oilfield applications, similar deposits are frequently found in cooling and boiler water applications. Physical water treatment devices have been used in these applications and are discussed in the literature[1]. Weatherford International's ClearWELL™ technology is a physical water treatment device that uses an alternating current (AC) signal to induce nucleation in aqueous environments[23]. The AC signal acts only to nucleate charged species which are already present under supersaturated conditions. The nucleation sites created by the device are primarily suspended within the aqueous fluid. This means that crystals forming on these nucleation sites are also suspended in the fluid and exit with that fluid.

These deposits can occur from any combination of inorganic or organic materials precipitating from the production liquid. These deposits typically form when the produced fluid undergoes a change. This change may be a change in temperature, pressure or fluid composition. Once deposits are formed they are removed either mechanically or chemically.

MAINTENANCE HISTORY

The Permian Basin region of Texas is well known for oil production. A very significant problem in this area has been associated with paraffin & scale deposits forming in producing wells. Deposits forming in these wells are responsible for a significant fraction of the well failures in this area and are often associated with mechanical failures of pumps and tubing. In severe cases the paraffin can exacerbate the failure costs when it is not the root failure cause due to being unable to unseat pumps. This results in increased maintenance costs due to having to "strip" rods from the hole. A graphical timeline of average failure frequency over time is seen in Figure 1. A breakdown of the root cause of those failures is presented in Figure 2. The historic data show that 34% of the observed failures are caused by foreign deposits.

NATURE OF PILOT STUDY

Beginning in mid 2006 ClearWELL™ physical water treatment technology has been introduced into oil wells in the central and Southern Midland basin. The initial targets for these wells have been wells with a history of problems associated with scale deposition. Table 1 contains results for some of the test sites. In this table the column days between failures represents the time between the last two failures observed for the well prior to the installation of the ClearWELL™ device. ClearWELL™ devices were installed on these wells soon after the last failure. Since introduction of the ClearWELL™ devices, these wells have no failures where the root cause could be attributed to paraffin or scale.

DISCUSSION

It was expected (and observed) that the ClearWELL™ device improved the performance of those wells with a history of problems associated with scaling. The remarkable result was the improved performance in wells where the primary historical failure mode was associated with paraffin deposition. Paraffin deposition problems can be roughly assigned to two classes. In the first class paraffin slowly builds on the pump rods. In this case paraffin deposition can be roughly monitored by monitoring the trace recorded by the load cell on the pump. Steady growth of paraffin eventually produces a condition where maintenance is required, but can be scheduled. The second class of paraffin deposition has both steady build up of paraffin, but accompanied by erratic growth which produces catastrophic failures. The erratic deposition schedule gives no prior warning of impending tube plugging or pump sticking. This mode of paraffin deposition is very undesirable, and appears to be largely prevented when conditions are favorable for ClearWELL™ operation. As seen in Figure 3, introduction of the ClearWELL™ device significantly changes the character and quantity of paraffin deposits

According to chemical thermodynamics, precipitation of solid will occur whenever the chemical potential of the dissolved species is greater than the chemical potential of the precipitated solid. That is when the free energy change for transforming dissolved substance to solid is negative. Equilibrium thermodynamics then predicts that precipitation will occur and continue until a condition is reached where the chemical potentials in the two phases are equal. This equilibrium behavior must be reached, but thermodynamics says nothing about the time that may be necessary for the transformation to occur. In real systems there are often complications. One of the chief complications is related to the energy required to form a new surface. During the early stages of formation of the new phase, the high surface to volume ratio creates a situation where not enough energy is supplied from forming the new phase to satisfy the energy requirements of forming the new surface. A homogeneous system that thermodynamics says must eventually form a new phase, is trapped in the dissolved state. If there is another surface already present where the dissolved species can preferentially adsorb, a crystal can grow, but only create a fraction of the solid-liquid surface required by a crystal growing from a homogeneous solution. This phenomenon is known as nucleation. When liquid flows in a pipe, the pipe surface can and does provide nucleation sites. These nucleation sites are then the primary growth sites for formation of the new phase and the material preferentially grows at the pipe surface. Scale formation on pipe walls eventually restricts fluid flow and can either freeze mechanical components or restrict the movement of mechanical components.
From an operational viewpoint this is a phenomenon to be avoided. In choosing a scale abatement strategy one needs to consider:

1) The type of scale formed
2) The degree of supersaturation
3) Locations where deposit formation are most problematic

The type of scale may restrict the type of approach used. For instance, the solubility products of most metal sulfides are so small that virtually any measurable metal ion concentration will be far in excess of the equilibrium value at and will precipitate immediately. The degree of supersaturation is a measure of how far from equilibrium the system is, systems far from equilibrium provide the greatest amount of scale, and may begin to nucleate without the presence of heterogeneous nucleation sites. If deposit formation is only a problem in a few sites of the system there may be opportunities to avoid scale problems by adjusting residence time or inhibiting the rate of solid formation. There are three basic strategies available to abate the problem.

1) Change the thermodynamic conditions so that the system remains unsaturated
2) Attempt to inhibit the kinetics of scale formation
3) Create nucleation sites that are not located on the pipe surface.

Changing the thermodynamic conditions so that the system is no longer unsaturated with respect to a scale species may be performed by either chemical sequestration methods or dilution. Chemicals may sometimes be used to inhibit the rate of scale formation. This and knowledge of residence times of fluid in the system may be used to avoid deposits in piping regions where the problems are most severe. Nucleation not only is the cause of scale problems, but can be used to minimize the problems associated with scale. If large numbers of nuclei are introduced into the liquid phase, the relatively small number of nucleation sites found on the pipe surface can be starved of species that deposit. This is the strategy adopted in the ClearWELL® device. The idea is that an impressed alternating current on the piping can induce electromagnetic fields on the pipe. Charged species moving in the pipe will then move in response to these fields. The small movements of anions and cations produce cells where the local concentrations of these ions are both higher and lower than those normally seen in the system. The cells which are of higher concentration have higher chemical potential for the dissolved ions and are more likely to form homogeneous nuclei. Once these nuclei form, bulk thermodynamics ensures that they grow. The real advantage is that these microcrystals grow within the fluid and the crystals move with the fluid. Because the electric current travels throughout the system there are an extremely large number of opportunities to form nuclei and the contribution of the nucleation sites on the pipe surface are overwhelmed by numbers.

Nucleation is a key process in the formation of any new phase. When paraffin molecules begin to crystallize from crude oil, they crystallize first on whatever solids are present in the system. If there are no solids suspended in the system, they crystallize onto pipe and pump surfaces. They do this because they are there and because they provide sites for nucleation. Close examination of a wax deposit, Figure 4, shows that paraffin deposits onto suspended inorganic materials, even in the absence of the ClearWELL™ device. When conditions are such that the ClearWELL™ device produces large quantities of inorganic material suspended in water, those surfaces are available to any paraffin molecules precipitating from the crude oil as in Figure 5.

Microscopic photographs have been obtained for wax samples obtained from wells where the ClearWELL™ device has been installed. Figures 6 is a photograph of a paraffin sample obtained from a site where the device is installed, and functioning. Figures 7 and 8 are microscopic photographs of wax samples obtained from a well at Henry Petroleum. These wax samples when the water cut had dropped dramatically and external evidence suggested that the ClearWELL™ device was no longer functioning to impede wax deposition problems.

The first photograph clearly show inorganic debris contained within the paraffin sample. The micro-photographs of the wax drawn from the wells where the water cut had dropped to near zero show only thick paraffin deposits. These photographs strongly support the hypothesis that the ClearWELL™ device functions to create small inorganic scale particles which then serve as nucleation sites for wax crystallites.

CONCLUSIONS

A physical water treatment device, known as ClearWELL™, shows remarkable performance in reducing the occurrence of well maintenance issues associated with foreign deposits. It has also demonstrated a reduction in expenses related to scale and paraffin aggravated pulling costs. ClearWELL™ functions both to reduce problems associated with inorganic scale deposits, but also to reduce problems associated with paraffin build up. It is hypothesized that the ClearWELL™ device reduces the problems associated with paraffin deposits by providing alternate nucleation sites for paraffin crystals and thus a means for paraffin crystals to remain suspended in solution or to form only soft deposits.

ClearWELL™ does not change the composition of the produced fluid nor the thermodynamic conditions at the well head. The state of dispersion of inorganic deposits is changed, allowing inorganic scale to remain suspended in a system with turbulent flow. The device itself only affects the nucleation of dissolved charged species present in supersaturated conditions. This means that its application requires a significant water cut that is supersaturated with respect to some mineral species.

Table 1
Failure History of Test Sites Pre and Post ClearWELL™ installation

Well	Failure Frequency	Days Between Failures	Days Since Last Failure
Well #1	1.6	227	460
Well #2	1.4	259	341
Well #3	4.9	75	470
Well #4	3.4	107	327
Well #5	1.1	326	368
Well #6	10.7	34	579
Well #7	2.4	153	684
Well #8	12.2	30	383
Well #9	1.2	295	530

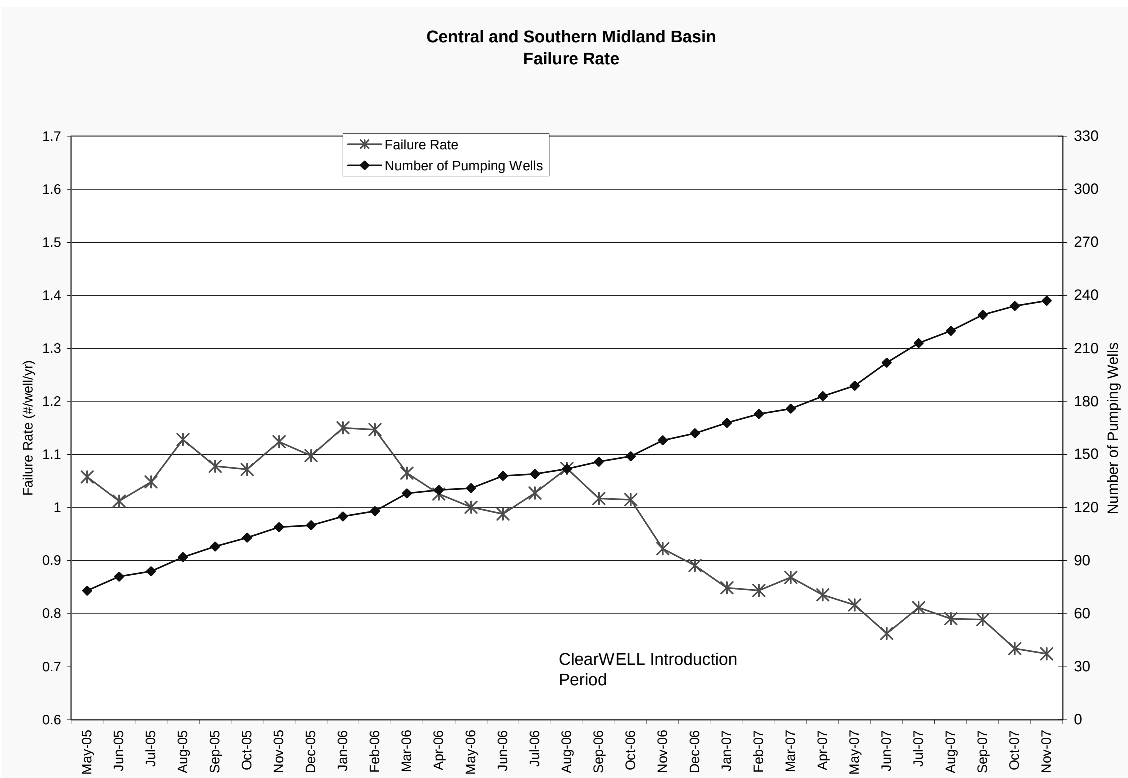

Figure 1 - Failure Rate and Number of Wells pumping in the Central and southern Midland Basis for the May2006-Nov 2007 time period. Significant numbers of ClearWELL™ devices were introduced into the producing wells beginning in mid 2006. Note the decline in failure rate occurring in this time period.

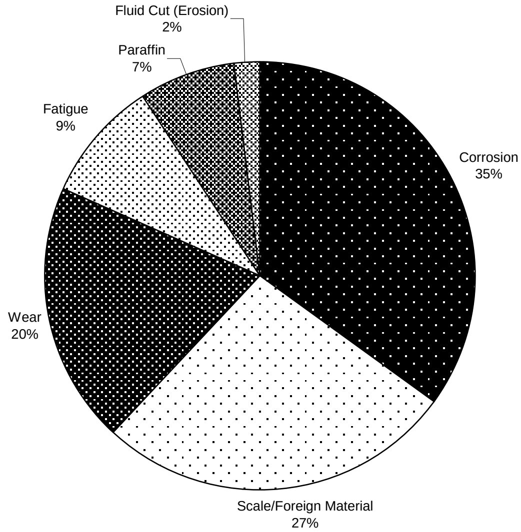

Figure 2 - Root Cause of Failures Observed in the Central and Southern Basin

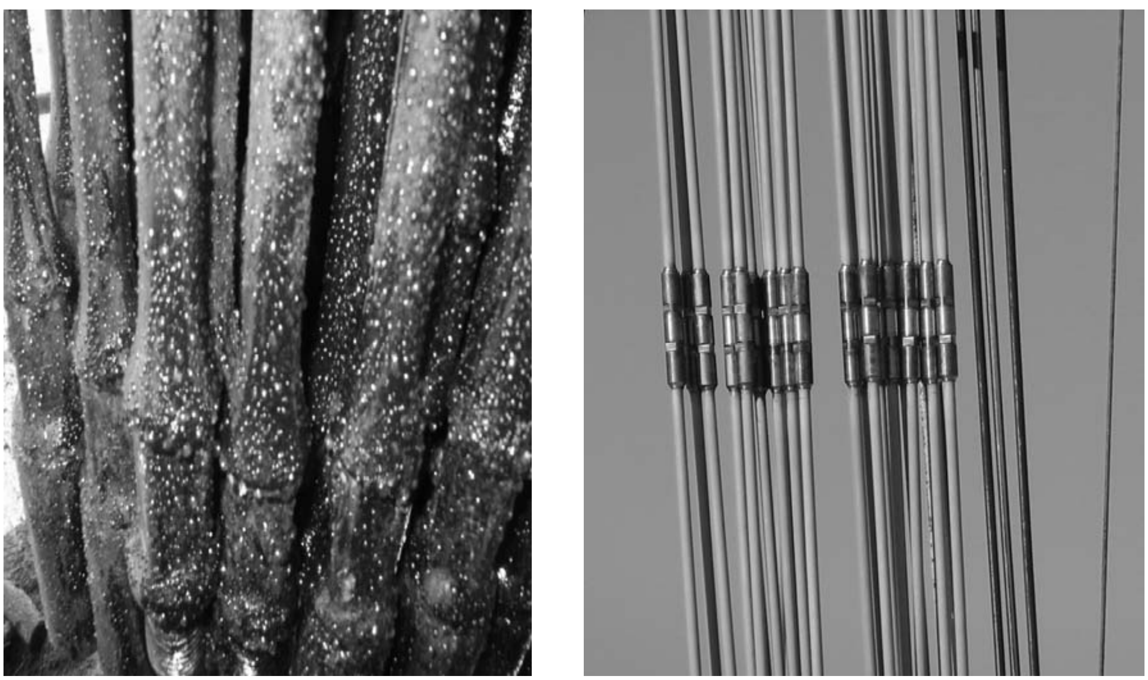

Figure 3 - Representative Paraffin Deposits Seen on Pump Rods Pulled from Wells Where ClearWELL™ is not in use (left) and in use (right)

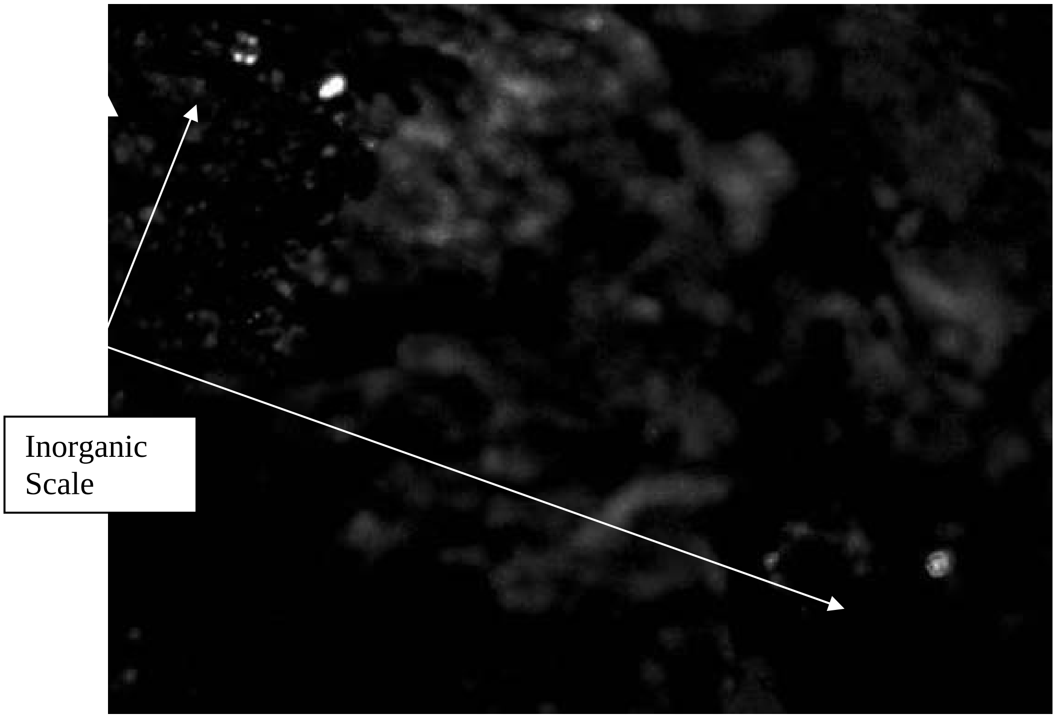

Figure 4 - Hard Paraffin precipitate from well not treated with ClearWELL™.

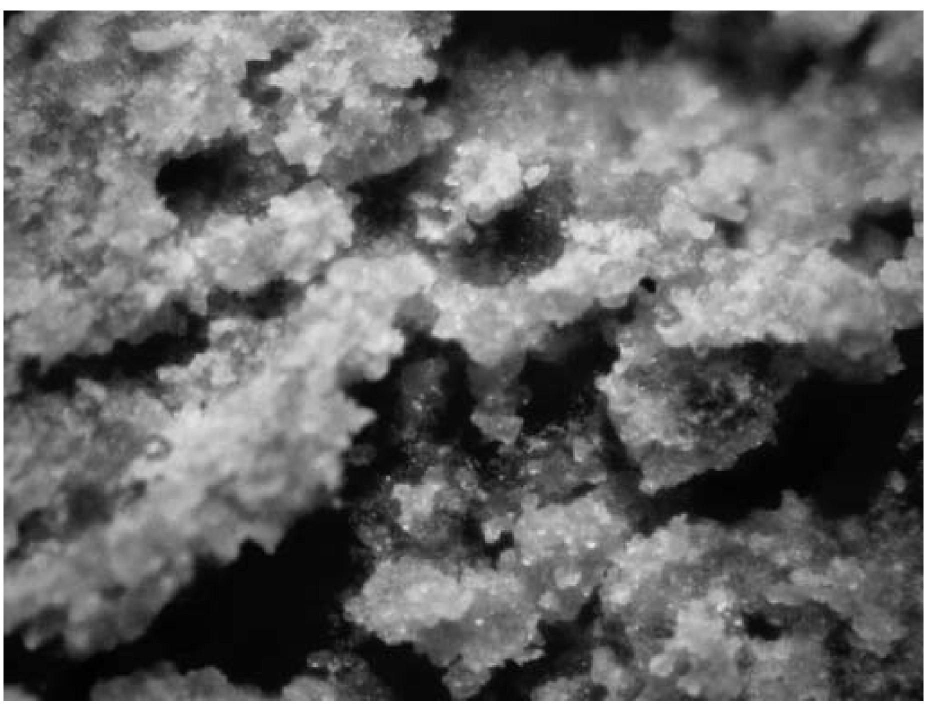

Figure 5 - Soft polycrystalline paraffin deposit. Sample taken from a well treated with a ClearWELL™ device.

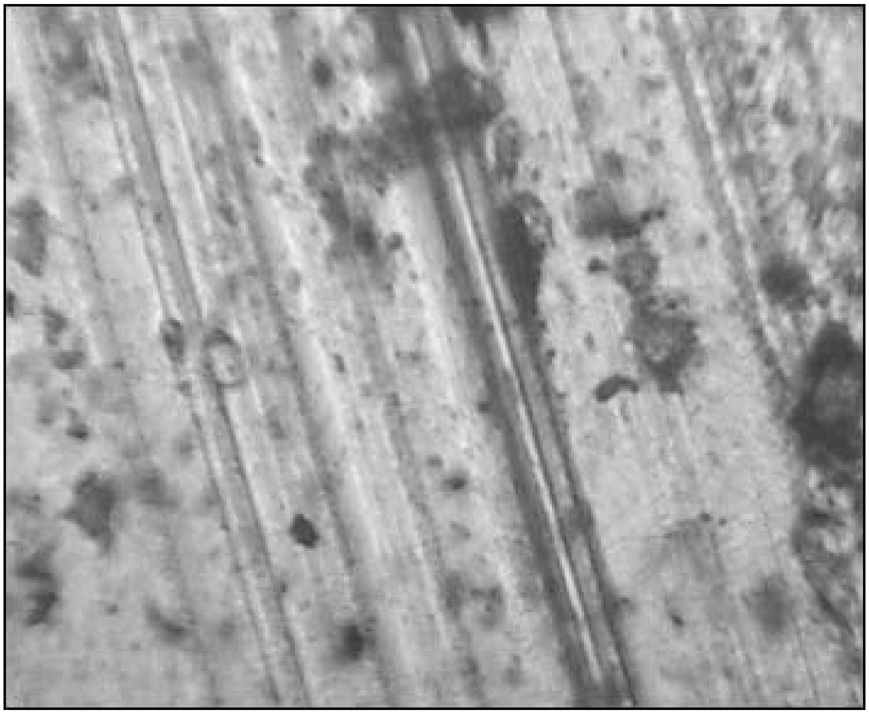

Figure 6 - Micrograph of paraffin sample obtained from a well with a functioning ClearWELL™ device.

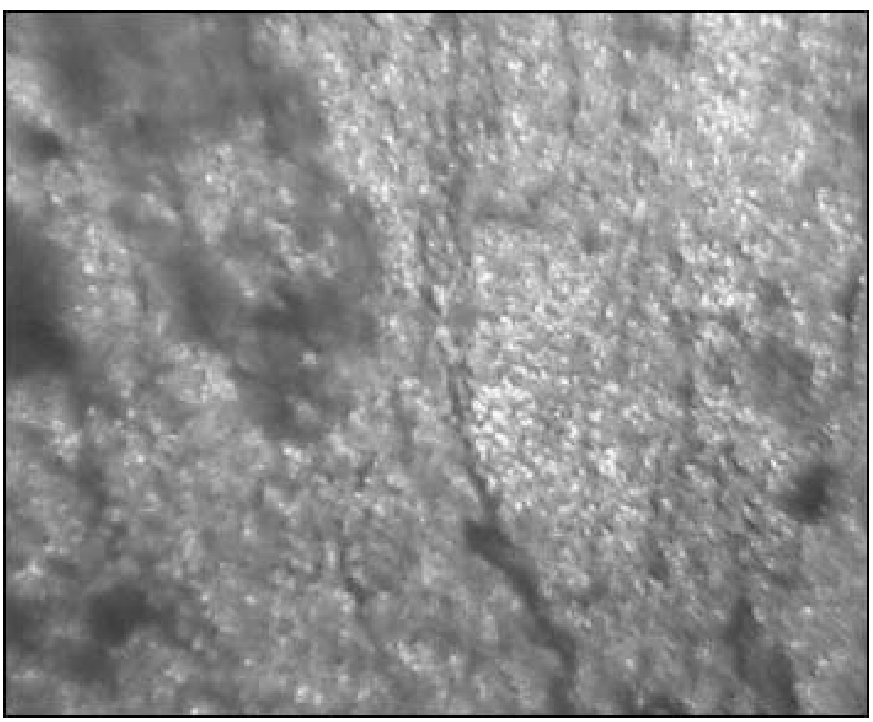

Figure 7 - Micrograph of Paraffin sample obtained from well where the water cut had reduced to negligible levels.

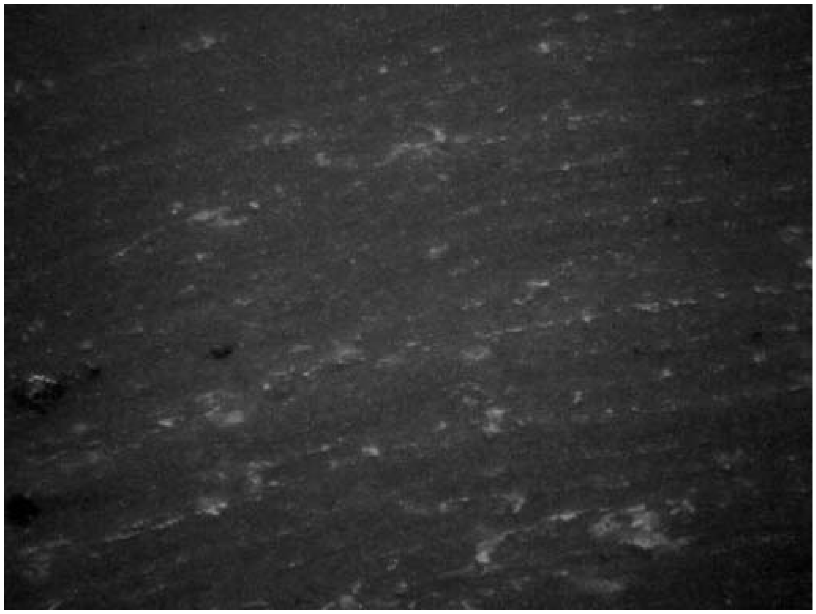

Figure 8 - Photomicrograph of a paraffin sample obtained from a well where the water cut has fallen to negligible levels.

[1] Y.I. Cho, S.H. Lee, W. Kim; *ASHRAE Transactions*, **109**, 346-357 (2003)

[2] K.Q. Zhang, X.Y. Liu; *Nature* **429**, 739-743 (2004)

[3] S. Kobe, G. Drazic, A.C. Cefalas, E. Sarantopoulou, J. Strazisar ; *Crystal Engineergin*, **5**, 243-253 (2002)