Practical Hot Oiling and Hot Watering for Paraffin Control*

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ABSTRACT

One of the common oil-field wellbore problems is paraffin deposition. Even though hot oiling or hot watering is usually the first method tried for removing paraffin, few operators appreciate the limitations of "hot oiling" and the potential for the fluid to aggravate well problems and cause formation damage. Field tests have shown that the chemical and thermal processes that occur during "hot oiling" are very complex and that there are significant variations in practices among operators. Key issues include: (1) During a typical hot oiling job, a significant amount of the fluid injected into the well goes into the formation, and hence, particulates and chemicals in the fluid have the potential to damage the formation. (2) Hot oiling can vaporize oil in the tubing faster than the pump lifts oil. This interrupts paraffin removal from the well, and thus the wax is refined into harder deposits, goes deeper into the well, and can stick rods. These insights have been used to determine good "hot oiling" practices designed to maximize wax removal and minimize formation damage.

INTRODUCTION

Many wells produce oil with the potential to deposit paraffin in the wellbore, tubing, flowlines, and surface equipment. Almost every oil producer encounters paraffin problems and often attempts to solve them by hot oiling or hot watering. Because hot oiling is so readily accepted, it is not commonly recognized that formation damage may occur due to the deposition of organic material over time.[1] Producers who are reluctant to introduce almost anything else into the formation will accept frequent hot oil or water treatments. Minimal thought is usually given to the physical and chemical character of the fluid being used and its potential to make problems worse.[2,3,4,5] Hot oiling or hot watering jobs are so common that it is taken for granted that they are being done properly even though their unpredictable effectiveness indicates poor practices. In this paper when referring in general to the process of pumping hot fluid down a well, we have used the term "hot oiling" to refer to the use of either water or oil.

When hot oil or water is injected into a well, it cools rapidly because significant heat is lost to the earth and the capacity of the well to absorb heat is typically large compared to the heat injected (see Appendix). The effectiveness of hot oiling depends upon the depth to which the well is heated above the wax melting point compared to the depth paraffin deposition occurs. Paraffin deposition occurs when the temperature is below the cloud point, the temperature below which the oil becomes saturated with wax.

*Originally presented as "Insights Into Good Hot Oiling Practices" --© Society of Petroleum Engineers--, SPE 25484, at the SPE Production Operations Symposium, Oklahoma City, OK March 21-23, 1993.

Part of this work was performed by Sandia National Laboratories managed for the United States Department of Energy under contract DE-AC04-94AL85000.

For low producing wells the temperature of the oil in the tubing is close to the temperature of the surrounding formation. Thus paraffin deposition can occur down to the depth where the temperature of the surrounding formation is warmer than the cloud point. Unfortunately the depth to which hot oiling heats the well above the wax melting point is seldom as deep as the depth paraffin deposition can occur.

Figure 1 shows downhole temperatures for the hot oiling of a well in Hughes County, Oklahoma. The figure shows that above 3200 feet the temperature of the earth drops below the cloud point and wax will be deposited inside the tubing. The temperature of the oil injected into the annulus exceeds the wax melting point only down to 500 feet. Thus from 500 to 3200 feet the temperature is not hot enough to melt the wax. Some of this wax can be dissolved by the oil due to the increase in solubility of wax with temperature. However, this does not normally remove a significant quantity of wax from the well.

The oil injected into the annulus in Figure 1 drops below its cloud point at 1400 feet. Thus the oil injected into the annulus to dewax the tubing deposits wax in the tubing-casing annulus below 1400 feet. This oil does not warm up above its cloud point before it reaches the bottom of the well. Thus, oil containing paraffin crystals is injected into the formation. Note that the stock tank oil used for the hot oiling of this well has a cloud point significantly above the produced oil. This is because of the removal of light ends at the separator and the accumulation of tank bottoms.

INSIGHTS INTO PARAFFIN PROBLEMS

The potential for paraffin problems and formation damage varies significantly. Even neighboring wells producing from the *same* reservoir can very significantly in paraffinic properties. The cloud point of an oil determines the oil's potential to create paraffin problems and formation damage. Cloud point depends upon the oil composition and is significantly affected by small amounts of high molecular weight paraffins. Pressure does not significantly affect cloud point for constant composition. A drop in pressure can result in a loss of light ends, concentrating high molecular weight paraffins and thus increase the cloud point. This apparent effect of pressure on cloud point is thus actually an effect of composition.

Most wells are hot oiled on a scheduled basis and, as a result, many wells are hot oiled that may not need treatment. Most operators do not inspect bull plugs, etc., for wax to determine when a well needs to be hot oiled. While this may seem to save effort or money in the short term, the risk of formation damage and workover costs may, in-the-long-run, be more significant than near term savings.

Stock tank oil can contain wax crystals, asphaltenes, scale, and corrosion products that are damaging to the formation. Paraffin tends to be more concentrated in the bottom of stock tanks. Microscopic examination of tank bottoms being used for hot oiling in Hughes County, Oklahoma, showed that one drop of oil contains 100,000's of particles 4µ or greater. Heating of the oil melts the waxes, but not asphaltenes. Figure 3 shows an oil sample taken after the oil was heated by the hot oiling truck. The particle, an asphaltene 40µ in size, was unaffected by the heat.

During a hot oiling job, fluid is injected into the annulus faster (~90 bbl/hour) than the sucker rod pump produces it back (~4 bbl/hour). Except for *very* tight formations, most of the fluid injected into the annulus flows out into the formation before it is produced back. The fluid does not normally stand in the annulus awaiting production. Thus, the fluid injected into the annulus can damage the formation if it is saturated with paraffin or contains contaminants either from the stock tank or hot oiling truck.

Normally, the vaporization of light ends in the hot oiling truck does not raise the concentration of paraffin in the oil that flows into the formation.[6] Any vapor generated in the hot oiling truck is pumped into the annulus along with the oil and dissolves back into the oil as it cools. As a result high molecular weight paraffin is not more concentrated than when it was pumped from the stock tank. If, however, the oil is preheated by circulating it back to the tank on the hot oiling truck, vapor escapes to the atmosphere and paraffin is concentrated.

It is fairly well recognized that the pumping unit needs to be on during hot oiling jobs. Otherwise, even though wax is melted, it is not produced. Wax not produced from the well during hot oiling is refined into harder deposits, can run down deeper into the well, and can stick rods. What is not commonly recognized is that just because the pump is on does not mean that the well is producing wax. If the pump is on but the well is only making gas, wax is not produced. Hot oiling can heat the oil in the tubing sufficiently to vaporize it. If oil in the tubing vaporizes faster than the pump lifts oil, the well will make only gas and wax is not produced.

The quantity of fluid pumped, pumping rate, and temperature of hot oiling jobs varies. The most thermally efficient hot oiling job delivers the maximum BTU in the shortest time using the least fluid. The skill of the hot oiling truck operator affects the BTUs delivered as does the condition of mechanical equipment on the hot oiling truck. The output of a hot oiling truck can either be BTU or flow rate limited, but it is usually BTU limited if the equipment is in good condition. Figure 3 shows the depth to which the annulus and tubing temperature are above the wax melting point as a function of time for a well in Hughes County, Oklahoma. At the rate pumped, one truck load was delivered in 28 minutes. After this time the benefit of additional fluid diminished.

If oil or water with the same total BTUs is injected at the same rate, the downhole temperatures will be within a degree or so. Many operators say hot watering is more thermally effective than hot oil because of the higher heat capacity of water. This ignores the fact that the process is usually limited by the BTU output of the hot oiling truck. Hot watering may inject more total BTUs but because of burner limitations it takes longer and so the benefit is not as great as presumed. Figure 4 compares hot water and hot oil for two wells in Burleson County, Texas. The wells have the same casing profile. Chemical considerations and the potential for formation damage, not just thermal efficiency, should be considered in deciding between hot oiling and hot watering.

GOOD PRACTICES

The primary factors that can be controlled during a hot oiling job are frequency, fluid (water or oil, fluid quality, additives, etc.), point of injection (into casing or tubing), quantity of fluid, temperature, flow rate, initial well conditions, tubing pressure, and pump operation. Good hot oiling practices constitute controlling these factors to maximize paraffin removal and minimize the potential for formation damage. These practices are summarized in Table 1.

Paraffin Treatment Should be Well Specific

Treatment should be based on the problems experienced. Hot oiling all wells on a lease may contaminate wells that would not ordinarily have a problem. Treating wells with excess fluid (i.e., heating below depth needed to melt paraffin present) increases costs and the potential for formation damage.

The Frequency of Treatment Should be Minimized

Bull plugs, etc., should be inspected to determine when the well needs hot oiling. Paraffin deposition in the tubing of a well is a continuous process. The rate of downhole deposition should not vary significantly with the season of the year. Wells should not be hot oiled more frequently in the winter just because flowlines need more frequent treatment at this time. Hot oiling too frequently increases costs and the chances of formation damage.

Good Quality Fluid Should be Used

The better the fluid quality, the lower the potential for formation damage. To minimize formation damage the cloud point *must* be lower than the formation temperature and *should* be lower than the minimum temperature during injection, then the oil entering the formation will not contain wax crystals. Circulating the stock tank or taking the oil from the top of the tank can improve oil quality. Hot oiling jobs should be planned so that the paraffin pumped out of one well is not used in the hot oiling of another well. Chemicals may improve oil quality and reduce the potential for formation damage. Switching to hot water does not necessarily eliminate the problem of particulates. If good quality water is a problem, treatment of the water should be considered.

The Fluid Should be Injected Down the Annulus

If the tubing and rods are coated with 1/16" of paraffin to a depth of 1000 feet, there is ~250 pounds of paraffin. If this paraffin is melted while hot oiling down the annulus and the well is producing oil not gas, the oil in the tubing carries the paraffin out of the well. If the well is hot oiled down the tubing, with more than one tubing volume, paraffin can be pushed into the formation causing damage (this paraffin will not be in solution at reservoir temperatures). Special precautions and treatment should be considered if it is necessary to pump hot fluid down the tubing.

The Tubing Should be Full and The Well Producing Oil, Not Just Gas

Gauge ports can be sampled as an indication of whether the well is making liquid. For paraffin to be removed, fluid must carry it out of the well. The upper part of a well can be full of gas because the fluid level is below ground level at the beginning of the job or because oil in the tubing is vaporized by the hot oiling job. The potential for the latter can be reduced by increasing the back pressure on the well. One way this can be done is by use of a back pressure regulator. Another way to reduce the potential for vaporizing oil in the tubing is to load the tubing with stock tank oil (dead oil) before the job.

The BTUs per Hour Injected Should be Maximized

Maximizing the BTUs per hour injected will increase the effectiveness of a hot oiling job. Establishing target values for temperature, flow rate, and leading and tailing non-heated volumes is one way of evaluating a hot oiling contractor's performance.

The Volume Injected Should be Limited

Only enough fluid should be injected to remove the paraffin or to reach a point of diminishing paraffin removal.[4] Unheated fluid pumped at the beginning and ending of the job should be diverted to the flow line. A thermal analysis can be used to decide how much fluid to inject. By minimizing the volume injected, formation damage is minimized and time to produce-back the fluid is reduced.

Thermodynamics Alone Should Not Be The Deciding Factor In Choosing Between Hot Oil And Water

The ability of the fluid used to clean the casing, wellbore, and tubing as it returns up the tubing is an important consideration. The only way to remove the paraffin left by hot oiling is to use the fluid injected as the cleaning solution. The use of surfactants in the hot fluid will help this cleaning process.

HOT OILING SPREADSHEET

A public-domain-software spreadsheet has been developed to estimate downhole temperatures during hot oiling jobs. This spreadsheet is intended as a tool for understanding the thermodynamics of hot oiling and for comparing hot oiling jobs, e.g., to investigate the effects of differences in casing profile, volume of fluid injected. If accurate predictions of downhole temperature are required, a more sophisticated code should be used.[4] While the spreadsheet formulas include a number of assumptions to simplify calculations, the primary uncertainty in the temperature estimates is probably due to uncertainty of what is in the hole surrounding the casing.

CONCLUSIONS

There is no one right way to treat all wells for paraffin problems. Different operators have adopted different approaches that have reduced costs and extended production. Some operators have stopped hot oiling or hot watering altogether, others only hot oil or hot water. When hot oiling or hot watering is appropriate, there are practices that maximize the potential for paraffin removal while minimizing the potential for formation damage. These good practices are not hard fast rules, but rather are principles to follow.

ACKNOWLEDGMENTS

This work is part of a US Department of Energy-sponsored Oil Recovery Technology Partnership project. The cooperation of the following companies is gratefully acknowledged: Edisto Resources Co., Grant Petroleum, IROC, JEDI Inc., JRB Oil & Gas Co., PGO Inc., and Siete Oil & Gas Co.

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APPENDIX: FLUID-STEEL EQUILIBRIUM TEMPERATURE (HOT OILING)

The average increase in temperature of the well $\left(T_{equib} - (T_{ho} + T_s)/2\right)$ can be calculated by equating the heat lost by the oil to the heat gained by the steel assuming no heat is lost to the formation:

$$A_{tc}C_O\left(T_{ho} - T_{equib}\right) = \left(A_sC_S + A_{rt}C_O\right)\left(T_{equib} - (T_{ho} + T_S)/2\right)$$

where T_{equib} is the fluid-steel equilibrium temperature, T_{ho} is the "hot oil" temperature, T_s is the surface temperature, A_{tc} is the area of the tubing-casing annulus, C_O is the heat capacity of the oil, A_s is the area of the steel (rods, tubing and casing), C_s is the heat capacity of the steel, and A_{rt} is the area of the rod-tubing annulus. Typical data are

$T_{ho} = 204° F$	$A_{rt} = .018 ft^2$	$C_S = 54 BTU / (ft^3 \cdot° F)$
$T_s = 65° F$	$A_s = .037 ft^2$	$C_O = 25 BTU / (ft^3 \cdot° F)$
$T_{bh} = 130° F$	$A_{tc} = .057 ft^2$	

From which $1.4\left(204 - T_{equib}\right) = 2.4\left(T_{equib} - 98\right)$. Solving for T_{equib} gives 139°F. Thus if there is no heat lost to the formation and enough oil is used to fill the annular volume once, the average temperature would be 139°F. Heat loses will make the actual average temperature less than this.

Table 1
Good Practices

- Paraffin treatment should be well specific.
- The frequency of treatment should be minimized.
- Good quality fluid should be used.
- The fluid should be injected down the annulus.
- The tubing should be full and the well producing oil, not just gas.
- The BTUs / hour injected should be maximized.
- The volume injected should be limited.
- Thermodynamics alone should not be the deciding factor in choosing between hot oil and hot water.

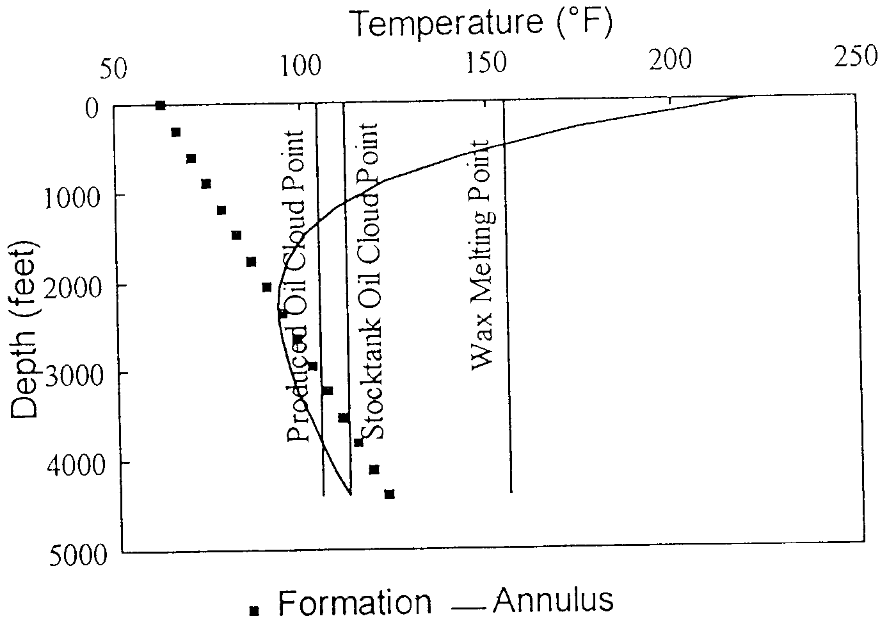

Figure 1 - A hot oiling that injects crystalline paraffin into the formation.

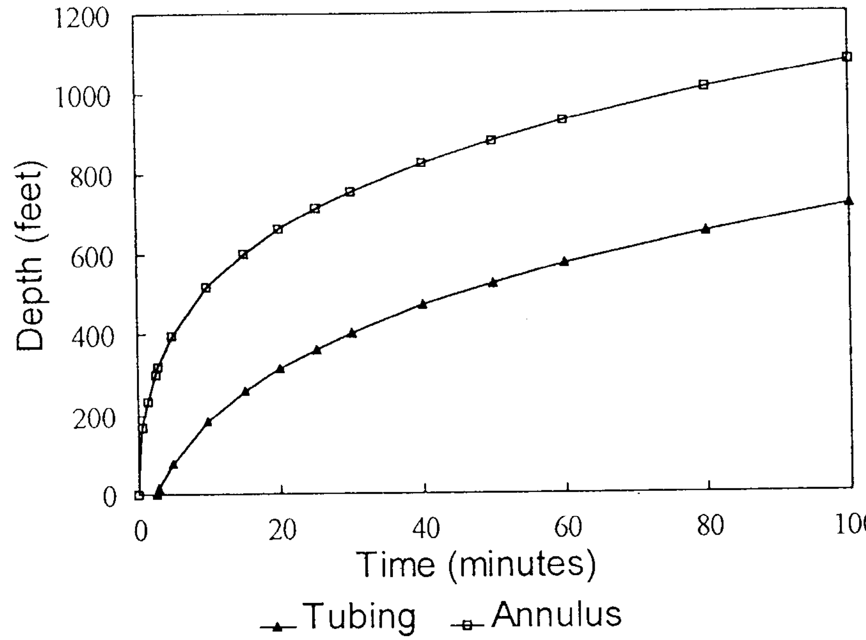

Figure 3 - Depth tubing and annulus temperature are raised above paraffin melting point.

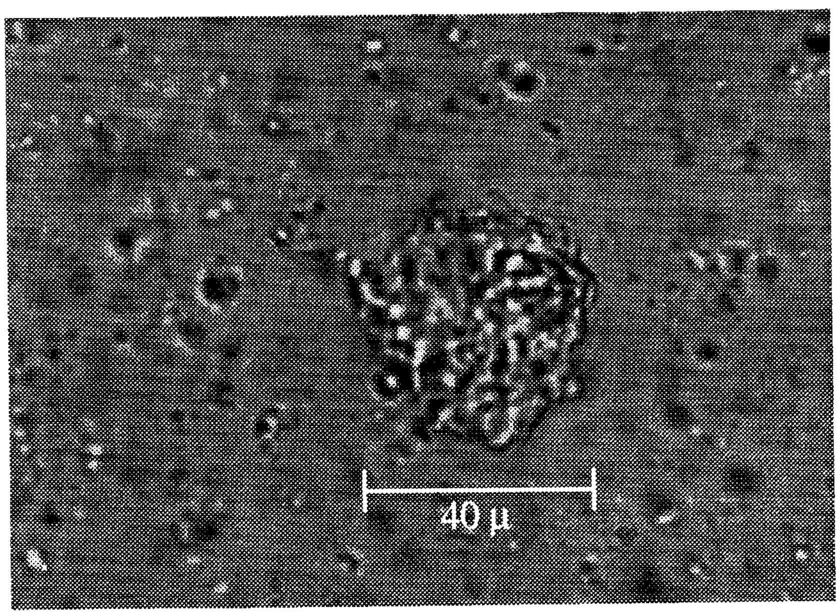

Figure 2 - Particle in oil as injected into annulus.

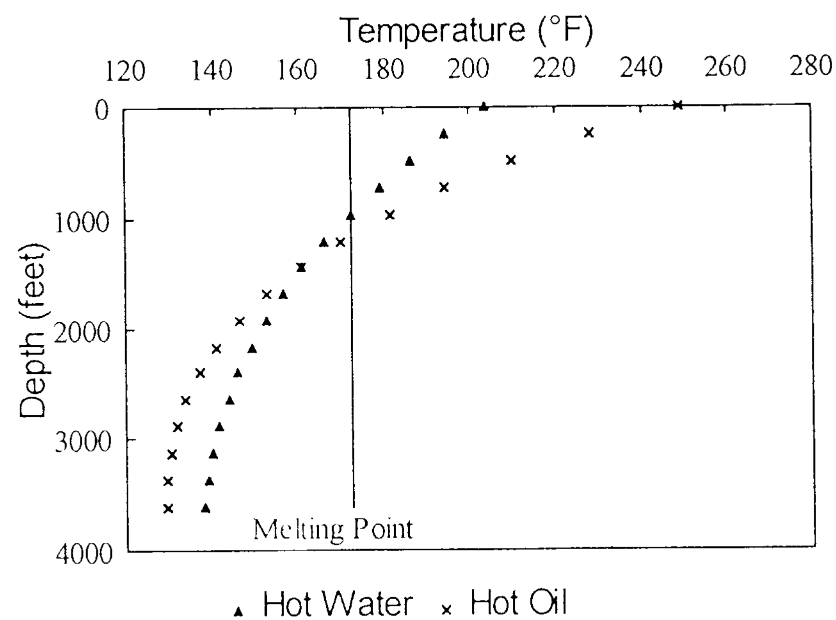

Figure 4 - Hot water vs. hot oil annulus temperature after the injection of 65 BBL (~35 minutes).