DISADVANTAGES OF HOT OILING: PART II – 30 YEARS LATER

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ABSTRACT

The use of hot oil as a paraffin removal technique is still used today in spite of its ineffectiveness in most wells. In 1982, the original paper on hot oiling recommended hot watering with chemical, which did not turn out to be the best alternative. In the past 30 years, we have learned much more about the paraffin problems we are trying to treat. A computer program from a Sandia National Laboratory Study, which was written in the 1990s, shows that you cannot melt most paraffin out of the tubing of wells. We learned that hot oiling and watering down the tubing of wells will reduce production. This paper will discuss other problems caused by hot oiling and cost-effective treatment methods that have been developed to take the place of hot oiling on most rod pumping systems. Case histories will be presented on the replacement of hot oiling with other treatment methods.

INTRODUCTION

The use of hot oil to clean crude oil production equipment is still a commonly accepted practice in the oilfield today. In the last 30 years a number of papers have been written about hot oiling and hot watering that have shown many more problems than presented in my original paper in 1982. Hot oiling is done down the casing and in the worst case scenario down the tubing. After giving my original paper thirty years ago I was told about a well in the Midland Field that was being killed by hot oiling down the tubing. The well had been re-completed into a new zone, packed off and when tubing paraffin deposition started to stick the pump the well was hot oiled down the tubing with 70 barrels of oil. This treatment was repeated every 6 weeks as oil production dropped from 22 bopd to 16 bopd to 11 bopd to zero production after the fourth job. Thirty years ago this was an expensive mistake but at todays oil prices it is a $750,000 mistake. Hot oiling is used before pump changes, pulling jobs, for production losses, to clean flow lines, interfaces or tank bottoms. It is so readily accepted that in many fields, wells are hot oiled on a regular basis (weekly, biweekly, monthly, etc.) without anyone really knowing if it is needed on every well. The major study of hot oiling in the last thirty years was funded by the Department of Energy and done by Sandia National Laboratory personnel. A computer program was developed that proves that in most cases hot oiling down the casing is not effective for removal of paraffin deposition in the tubing below 1000 feet deep. In many fields hot oiling increases the costs of producing oil and may lead to many problems that would not occur if the wells were not hot oiled. In the original paper we recommended the use of hot produced water with chemical to replace hot oiling. Unfortunately, the use of too little chemical has made hot watering a problem in a number of fields.

HOT OILING PROCESS

The hot oil process involves using a truck equipped with a heater. Oil is obtained from the bottom of the Lease Sales Tank. The truck transports it to the well, flow line or tank to be cleaned. A hose is connected to the wellhead, the well is placed on manual, if on time clock or pump off controller, to start the pump, cold oil is pumped and then the heater is ignited and the temperature of the oil increases to desired temperature. The pump rate of the oil is maintained so that the oil exiting the firebox is maintained at the desired temperature (140-300°F). Some oil may be pumped into the flowline initially, to clear any paraffin from the wellhead area. The remainder of the oil is pumped into the annular space of the well. Sometimes the final few barrels will again be diverted to the flowline to clear any remaining paraffin from the flowline as the fire is turned off and the firebox cools off. It is assumed that when the truck drives off that an effective job has been done and all the paraffin has been removed from the well and flowline.

This process is basically a thermal process. It was assumed in 1982 that the hot oil was hot enough that it melted all the paraffin out of the tubing and flowline because the wellhead was >200˚F during the entire time heat was being applied by the heater. Unfortunately, the Sandia Heat Transfer Program shows that the earth is such a big heat sink that hot oil going down the casing rapidly losses heat to the earth and is less than 150˚F by the time it reaches 1000 feet down the casing. The paraffin in the tubing is actually higher melting as you go down the well making it impossible for standard hot oil trucks to remove paraffin below about 1000 feet. Of course, some oil only deposits lower melting paraffin so some hot oil jobs can be effective or slowly leave behind high melting paraffin after each job. The hot oil pumped down the annulus never contacts the paraffin in the tubing. Heat from the hot oil is transferred into the tubing string and this heat melts the paraffin off the walls of the tubing. The melted paraffin dissolves into the oil in the tubing and is carried from the well. The hot oil never contacts the paraffin in the tubing, it continues to fall to the bottom of the well (losing heat continually), and reaches the formation at the formation temperature or below and is produced back over the next several hours as ambient temperature oil. It is often observed when pulling a well after hot oiling that the rods have some paraffin remaining on them. This occurs because the rods receive less heat since they are in the center of the tubing and only the lower melting paraffin is removed.

This hot oil process, to remove accumulated paraffin deposits, has a number of inherent problems some of which were not discussed 30 years ago.

PROBLEMS WITH THE HOT OIL PROCESS

1) Source of Oil – The sales tank is the source of the oil for a given well or lease. The sales tank oil has a number of problems that make it very undesirable for use:
It is usually the coolest temperature in the system causing more paraffin to be out of solution.
It contains the oil with the least gas content in the field but the highest concentration of long chain, high melting paraffin.

The resonance time in the tank allows any paraffin, asphaltenes, solids, emulsion and any chemicals that are attached to them to settle out.

Paraffin removed from the tubing or flow line in a system ends up in the sales tank making it the oil with the highest concentration of paraffin in the system.

Any oil soluble chemicals used in a given field, including demulsifiers, corrosion inhibitors, paraffin surfactants, dispersants or crystal modifiers, asphaltene dispersants or inhibitors, biocides, solvents and possibly drilling/completion/acid additives can be found in the tank oil. Many of these chemicals can cause emulsions, oil wetting of solids or the permeability of the formation which can change rock to oil wet and increase water production.

In the past I have actually been told by a producer that he did not have tank bottom problems because he Hot Oiled with the bottoms. At the time, early in my career, I assumed he knew what he was talking about but can now respond that you don’t get rid of something by putting it back down a well that produces back to the same tank.

2) Trucks used for Hot Oiling – The trucks used to hot oil wells are limited by their burner heat capacity to a maximum rate of 1-2 barrels per minute to maintain oil temperatures exiting the burner at above 200˚F. These limitations cause a number of problems that have been written about in papers by other authors.

Safe heating of oil requires the truck to start pumping ambient temperature contaminated oil while the burners are being warmed up. This means up to 5 barrels of oil may be pumped down the annulus before the oil reaches 200˚F which means tank bottom paraffin particles may be not melted by heating process. A lab experiment preformed at Sandia National Lab actually showed some high melting paraffin may not be melted back into solution even when the oil is exiting the hot oil truck at 260˚F. The speed with which the oil is heated from ambient temperature on the truck and cooled in the annular space by the earth may not allow enough time for larger pieces of paraffin to be melted. It must be realized that the heating process from truck to the bottom of the well is only a matter of minutes; the oil is never held at the 260˚F temperature. In order to make hot oil effective at removing paraffin from the tubing to 2000 feet at least three hot oil trucks would have to pump down the well at the same time increasing flow to 4.5 barrels of oil per minute. This would still not insure that all the paraffin was totally melted before being pumped down hole or that the first 15 barrels pumped while the burners were warming up did not damage the formation. A field trial of the “Ultimate Hot Oil Job” was once done in Wyoming to convince operators that hot oiling could not remove paraffin to the bottom of the well. This experiment was done by setting a frac tank at the wellhead and preheating 120 barrels of oil to 160˚F by circulation. The 160˚F oil was then pumped into the annulus of the well at 5 barrels a minute with the burner on maximum. The oil entered the annulus at 220˚F at 5 barrels a minute for 20 minutes. The oil company then pulled the well to determine how deep the paraffin had been melted off the rods. It was determined that this Ultimate Job” had only removed paraffin to 900 feet below ground level while paraffin deposition went down to 2300 feet. The experiment was repeated on the same well using hot produced water heated to 160˚F but the exit temperature at 5 barrels a minute could only be held at 200˚F, due to the density of the water and the fact it takes 2.8 times as many BTU’s to heat water. The well was again pulled and paraffin removal had been achieved to 1100 feet still well short of the 2300 feet at which paraffin starts to deposit in this well. A third treatment incorporating chemical into the hot water was preformed on the same well and successfully removed paraffin to 2300 feet based on the third pulling job. See reference paper SPE 55800.

2) Heat Loss During Hot Oiling – Papers have been written showing that hot oiling cannot effectively heat a well to the pump intake, see SPE 18889, which shows 275˚F hot oil jobs pumped at 1.7 barrels per minute using 115 barrels and 142 barrels of oil actually cooled the annulus at the end of tubing by up to 10˚F from a 125˚F formation temperature. A second field test, in this paper, describes how a 400 barrel hot oil job down the tubing of a 6380 foot well raised the formation temperature from 127˚F to 175˚F, momentarily, which stabilized at 143˚F without pumping. This shows only a 16˚F increase in bottom hole temperature which was not sufficient to increase production by removing prior paraffin damage.

Another paper presented in the 1994 SWPSC by Sandia National Laboratory and Petrolite discussed a computer program, The Heat Transfer Program, that calculates the temperature of hot oil in the annulus and the tubing compare to the paraffin melting point and cloud point of the oil being produced by the well. The computer program was validated by placing temperature recording chips in specially designed couplings at various depths in a rod string which recorded the temperature of the oil in the center of the tubing as the well was hot oiled. These tests showed the computer program to accurately predict the temperatures achieved by a hot oil job within 100 feet. By inputting data on the well, geothermal data, oil, hot oil job and production rates a graph can be generated showing how deep a particular hot oil job is expected to remove paraffin as compared to how deep the paraffin is expected to deposit based on the oil’s cloud point. Based on this computer program a standard hot oil job down the casing, pumping 250˚F oil at 1.5 bpm can only be expected to remove paraffin to approximately 700 – 1000 feet from the tubing. Based on this program it is also possible for the tank bottom being pumped into the casing to deposit paraffin in the casing as its temperature drops below the cloud point of the tank bottom oil being used to hot oil with.

Hot oiling of flow lines, gathering lines or pipelines is another area where heat transfer is a problem. In order for hot oiling to completely clean paraffin from a line or any kind you need to know the melting point of the deposit you are trying to remove. The hot fluid must then be pumped at a high enough rate and temperature to raise the exit end of the line at the battery or vessel above this melting point. If this is not done then paraffin will be left in the line at some point. After repeated hot oiling leaving paraffin in the line plugging of the line should be expected. One method to avoid this is to have the line divided into short section which can be hot oiled with the injected oil only cleaning short distances and the removed paraffin and hot oil is caught in a truck and taken to the facilities for processing. This method of course adds tremendously to the cost of cleaning the line and with so many outlets may pose a large leak risk should one of the valves fail.

3) Formation Damage – As previously discussed Hot Oiling down the tubing can be the most effective at transferring heat to the bottom of the well. It is also the most effective way to damage a formation depending upon the amount of oil used and amount of paraffin dissolved or displaced from the surface of the tubing and rods. Many companies will hot oil down the tubing to keep from having a pulling unit stick a pump as it is being pulled. This is to keep from having the pulling rig sit while waiting for a hot oiler to come to the well after the pump is stuck. For this reason, in many fields, all wells are hot oiled before pulling to save money which may cause formation damage which costs much more than finding out which wells need to be hot oiled by sticking a pump.

Formation damage also occurs when tank oil loaded with paraffin, Asphaltenes or solid particles is pumped down the casing of wells. This occurs because a 70 barrel load of oil often exceeds the formation pressure causing the oil to go into the most open flow paths. During the 5 year Sandia National Laboratory Hot Oil Study experiments were done to determine the fluid level in the annular area after a hot oil job. It was found that based on bottom hole formation pressure that a 70 barrel load can all go into a formation within 3 minutes of finishing the hot oil job. Since the permeability determines the size of particle that can be carried into a reservoir any particles from the tank can plug the perforations and reduce production of oil, water and gas.

Other possible damage can be caused by the rate at which the oil enters the permeability. The formation permeability is so small even low flow generates high shear which can cause emulsions based on the type of oil/water ratios and chemicals contained in the oil used to hot oil with.

If hot oiling is done down the tubing or casing attention needs to be paid to production rates following these treatments over a period of time. Wells will generally let you know what treatments are good for production or bad for production.

4) Delayed Production – One of the hot oil costs that is often overlooked is when the oil used to hot oil, either down the casing or tubing, goes into a low pressure formation and is only produced back at the normal production rate.

If a well is hot oiled with 70 barrels of oil and almost all of it goes into the formation it may take a number of days to get the fluid back to the surface. For example, if a formation normally produces 10 barrels of fluid a day and a 70 barrel hot oil job is done it may take 6-7 days to start making new oil again. So if normal oil production is 6 barrels of the 10 produced the hot oil job costs you a minimum of 36 barrels of oil in addition to the cost paid to have the oil heated and pumped.

Basically you are paying a hot oiler to stop production of new oil for a number of days without removing all the paraffin present in the well.

5) Well Type – The ability of hot oil to clean a well has been discussed and it’s effectiveness in many cases is in doubt. In some wells the hot oil can cause immediate problems.

Wells that are on pump off controllers or time clocks, our low producers are most likely to experience this immediate damage. Timers or pump off controllers stop the well every so many minutes or hours depending upon the rate of fluid entry into the well. They are utilized to stop pounding or pumping when no fluid is entering the pump. When the well is shut down the free gas in the tubing rises to the top of the tubing, a free oil layer collects below the gas layer and below that is an emulsion layer, if present, and free water at the bottom. Depending upon the depth of the well, shut in time and amount of free gas the gas layer may be more than 1000 feet at the top of the tubing. If a hot oil truck pulls up to the well when it is shut off the common practice is to place the well pump switch on Manual, to start the pump, hook up the hot oil lines to the well and then start pumping oil. The problem arises if the well does not start producing fluid out of the tubing before the hot oil reaches the melting point of the paraffin in the upper tubing which may be still full of gas. If this occurs then melted paraffin may actually run down the tubing until it fines the oil fluid level where a layer of melted paraffin develops. If this layer is not produced out of the tubing before the heat is stopped then an instant stripping job may occur depending upon the melting point of the paraffin. Even if the paraffin is moved to the top of the tubing the gas that was displaced may leave the flow line full of gas and the paraffin will totally fill the flow line and solidify.

I actually watched this happen in a field in Southern Texas. I was working with the hot oiler and catching samples from the tubing as the hot oiler applied heat at 3, 6, 9, 12, 15, 18 and 21 minutes into the 70 barrel jobs. The first six wells had fluid coming out of the tubing immediately but when we got to the 7^{th} well nothing but gas was produced for the whole 21 minutes. As the hot oiler started cooling down the burner the rods started to hang up and before more oil could be applied the rods hung up and the well shut down. The well was pulled and stripped and the top 7 joints of tubing and rods were found to be totally clean but the next 4 joints were totally plugged with paraffin. Melted paraffin had run down the tubing because no fluid was being produced.

PROBLEMS WITH THE HOT WATER PROCESS

Hot water is an alternative to hot oil which I recommended in the first paper 30 years ago. I have learned since that it may not be as great a substitute as I thought.

1) Quality of Water Used – Water quality varies greatly from field to field with Total Dissolved Solids, scaling tendencies and availability being some of the concerns. The water treatments recommended in the last paper were to contain surfactants to help the water remove paraffin as it was produced up the tubing at ambient temperature. Unfortunately, many oil field waters contain greater than 140,000 ppm of Total Dissolved Solids that make them hard to disperse chemicals into, other than water soluble surfactants. It has also been found that the water soluble chemicals do a poor job of paraffin removal at ambient temperatures as they are produced up the tubing. The best chemicals are oil soluble, containing solvents to penetrate the paraffin to carry the surfactants to the pipe walls. In order to use oil soluble chemicals the water TDS must be reduced below 140,000 with the use of fresh water.

Another problem is the iron sulfide or formation solids that may be dispersed in the water. It is recommended that this water be filtered before being used to hot water with. A study done by Sandia National Laboratory and a filter company showed slow filtration of water into a holding tank to be used for hot watering is best to extend filter life.

As recommended previously if a water has scaling tendencies, bacteria problems or causes corrosion then appropriate chemicals should be added to the water used in addition to the surfactants to remove paraffin.

2) Trucks used for Hot Watering – The trucks used to hot water oil wells are limited by their burner heat capacity so when using water the cost of heating the water to a specific temperature will be almost three times the cost of heating oil. The burner can be scaled up if the water used has high temperature scaling tendencies and should be checked and scale chemicals added if needed.

The hot water if heated to the same temperature as the oil will carry heat approximately 200 feet deeper than the oil to remove paraffin. Since many paraffin problems will happen below the depth that can be heated to the chemical used needs to be tested at temperatures seen as the water is produced back to the surface.

3) Heat Loss During Hot Watering – The Sandia National Laboratory Heat Transfer Program will also calculate the heat transfer for water treatments based on the input values for a particular well and water density. It shows that in most cases the heat is not great enough to remove paraffin from the tubing and so the chemical removal of paraffin as the water treatment exits up the tubing is critical to completely clean a well.

Treating flow line paraffin deposition can be successful as can hot oil if the exit end of the line is heated above the meting point of the paraffin. To keep from having interface or tank bottom problems the water will need to contain some surfactants to water wet solids in the paraffin so it can disperse into the oil in the separator.

4) Formation Damage – The primarily causes of formation damage from a hot water treatment will be from loss of water to the formation which may cause water blocks, solids carried into the perforations or the formation of scale particles during the heating process and chemicals that cause emulsions to form when the treated water mixes with the produced oil in the formation.

Testing should be done to check for these problems and fluid levels may need to be shot immediately following a hot water treatment to see how much water is entering the formation

5) Delayed Production – Loss of water can delay the production of new oil just as described in the hot oil section.

6) Well Type – Hot water jobs can also cause problems in wells with pump off controllers or time clocks.

POSSIBLE SOLUTIONS TO THE PROBLEMS WITH HOT OIL AND WATER

1) Wells producing large volumes of fluid or gas can be treated with hot water and chemical treatments as long as testing is done to solve any water quality issues and enough paraffin remover is used to remove paraffin as the water is produced back up the casing. To make sure these treatments are working samples of the returning fluids can be caught out of the well head flow line to make sure paraffin is being removed.

Flowing wells can be treated with either a continuous injection down a capillary line using a crystal modifier or dispersant. If the problems are occurring in the formation or are very frequent plugging problems the wells can be squeezed with crystal modifier to inhibit deposition.

2) Wells producing low volumes of fluid or that produce on pump off controllers or time clocks can be treated with low volume cold truck treatments of ambient temperature water. Smaller treatments will not go into the formation

and can be sized for individual wells. Higher rates of chemical may be required as contact time with the paraffin in the tubing will be reduced. It should be remembered that a cold treatment pumped at 1 barrel per minute will reach the pump intake at the same temperature as a large heated treatment at 1.5 bpm.

Wells on time clocks may not return the batch treatments fast enough to do a good job of paraffin removal. In these wells small treatments with winterized crystal modifier can be loaded into the well at high ppm levels that will slowly be diluted over a couple of weeks to keep the paraffin soft enough that the pump can be pulled.

Solvent treatments have also been found to be effective on wells with lower melting paraffin, < 160˚F.

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