PRACTICAL PARAFFIN SOLVENT TREATING CONSIDERATIONS

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ABSTRACT
The removal of paraffin deposition in rod pumping wells has cost the industry billions of dollars over the years in direct and indirect costs. Once deposited, indirect heating of the paraffin by using a hot oil truck is the most common treatment. However, since hot oiling typically has been proven to be ineffective below about 500' (and in many cases, less than 100') solvents are a useful alternative. This paper summarizes some of practical aspects of solvent treatments and basic economic considerations. Preliminary evaluation of hot oiling effectiveness, melting point testing, solvent selection procedures and field pumping concerns will also be addressed.

BACKGROUND

While annular hot oiling of pumping oil wells is intuitively simple to understand, the actual process is far more complicated and perhaps one of the more misunderstood routine expenditures in the industry. This lack of understanding has resulted in enormous direct and indirect costs to industry.

The first intuitively simple aspect of hot oiling is that heat imparted to the wellhead area and the flowline generally succeeds in melting the paraffin where lease operators can visually see the results.

The second intuitively simple aspect of hot oiling is that hot oiling down the tubing during repair jobs is known to melt and clean up entire stings of tubing. Pulling unit operators, field supervisors, and lease operators all have first hand visual experience of this apparent success of hot oiling. Unfortunately, this process applies heat and solvent (heated lease crude) directly down tubing that is largely insulated with the gas in the annulus. The ability of direct injection down tubing to remove paraffin at great depths is easily understood and confirmed visually.

However, the intuitively simple aspects of hot oiling down the tubing hide the far more complex problems with hot oiling wells down the casing by tubing annulus, particularly with regard to the effective depth of treatment. This annular process does not directly mix fluids while the treatment is hot. More importantly, there is little or no insulation on the outside of the casing. In most casing and tubing configurations, the casing represents approximately 2/3 of the cross sectional area of the steel where heat transfer occurs.

Combined with surface losses and other practical considerations, approximately 80% of the heat at the burner tip of hot oiler is not being delivered into the tubing to melt paraffin. The remaining 20% will likely remove paraffin only near the wellhead and pumping tee. The remainder of the heat is spent quickly while moving down the annulus. Unlike hot oiling down the tubing, annular hot oiling is severely depth limited.

Unfortunately, the apparent "success" of pumping tee clean-ups and the other simple aspects of other hot oiling experiences have clouded the understanding of most operators. There are published field tests showing effective hot oiling depths of less than 500' and research modeling at Sandia National labs showing effective treating depths well less than 1000'. In fact, certain configurations of casing in the winter will not be treated to a depth of more than 50-100'. Despite this information, surveys of professionals with vast operational experience still show people believe treatments are effective at removing paraffin to 1500', 2000', 2500', and even deeper.

PRACTICAL PARAFFIN TESTING

Paraffin deposition is far more complex than is commonly understood. Shallower paraffin is typically harder than paraffin found further down the well. Crude oil compositions, production rates, BS&W production, casing configurations, temperature profiles, gas separation, differences in pumpoff control are all factors that affect the profile of paraffin deposition. The best way for the depth of paraffin deposition to be determined is from pulling the rods without hot oiling down the tubing when the pump is pulled. The paraffin typically transitions from heavy, hard, and thick at the top of the tubing to greasier, softer, and thinner further down the tubing. Paraffin can also trap and collect salts, scales and corrosion products. These contaminants also aggravate the paraffin problem because they can provide nucleation sites for paraffin deposition.

A worst case estimate of paraffin treating depth can generally be made by determining the melting temperature of paraffin samples from the flowlines. Unlike cloud point measurements that focus on the generation of paraffin, melting points focus on removal of paraffin after it is formed. Table I demonstrates the melting point of various field paraffins. These temperatures are then compared with the temperature profile in the well. If the reservoir temperature is above the melting point temperature of the paraffin, the paraffin problems are not likely to be in the formation near the wellbore. In these cases, the paraffin position is generally limited to cleaning up the tubulars further up the hole. Table I shows examples of actual paraffin samples from the field.

Once the melting point has been determined, another very practical test can be performed to assess an operator's current hot oiling process. With today's infrared temperature guns, various points can be tested throughout the hot oiling process. The recommended sampling points include the temperature gage on the hot oilier for reference calibrations. The second location is the point of departure from the truck to assess truck losses. The third is the side casing inlet valve to assess the line losses. The fourth and most important location is the pumping "T". The pumping "T" location should be monitored after the end of the job until the temperature decays to less than the melting temperature of the paraffin or the temperature prior to the job. After the hot oil treatment is pumped, the treatment is typically on a vacuum and the tubing is suspended in a column of gas with limited thermal conductivity. If the assumption is made that losses from the tubing are minor after the treatment, the temperature decay at the end of the treatment represents the depth from where the temperature originated. If the pump is in good condition, the wave equation can be used to determine the pump capacity of the well. In effect, the temperature versus time decay can be converted to a temperature versus depth curve. Once the flowline temperature drops below the melting point of the paraffin, the depth of effective hot oiling can be determined. Table II shows the results of actual hot oiling audits in the field.

IMPLICATIONS OF MELTING TEMPERATURES

The implications of paraffin melting temperatures are significant. Paraffins with higher melting point temperatures will generally exist further down in the well. The thermal energy of annular hot oil treatment dissipates with depth to a point where the "hot oil" is no longer melting paraffin. The intersection of the decayed temperature with melting point of the paraffin occurs much shallower with higher melting point paraffins. Both factors work against successful annular hot oiling. There is more potential for paraffin in the well and the limitations on effective heat transfer at high enough temperatures limit the effective treating depth. To illustrate the effective of melting point implication, one actual treatment had a flow line temperature at the end of pumping an annular hot treatment of 162F. If the melting point was above 162F, little or no paraffin would be melted. For this configuration and decay profile, paraffin with a melting point of 150F calculated a treating depth of approximately 50'.

Perhaps more critical is the situation where the melting point approaches or exceeds the formation temperature. Melting points above the formation temperature create a real potential for primary paraffin deposition in the formation. Secondary deposition into the formation from paraffin in the hot oil treatments adds to the problem. Once the paraffin deposition occurs in the formation, removing the formation damage can be extremely difficult. High grade solvents have limited contact time, contact area at a pore throat level is reduced, and getting heat into the formation long enough to melt the paraffin plugging is equally as difficult.

SOLVENT SELECTION

If solvents are used as an alternative to hot oiling for paraffin removal, several factors should be considered. There is tremendous bias in the chemical industry towards aromatic solvents like xylene and toluene. These solvents are considered the best because of the speed at which they dissolve paraffin and the amount of paraffin they can dissolve per gallon. The bias towards these materials is also likely related to formation treatments where the pore level contact time is very limited and premium performance is critical.

However, aromatics are expensive and are not necessarily the most cost effective material for tubular treatments. Unlike formation treatments where the solvent is expected to be in close contact with the paraffin, solvent treatments for tubular paraffin are pumped down the annulus and commingle with crude oil when they enter the pump intake. The mixture is pumped up the hole and dissolves the paraffin closer to the surface. The solvent essentially extends the ability of the crude oil to dissolve paraffin. Conversely, the crude oil dilutes or spends some of the capability of the solvent.

To understand the relative cost of treating tubing with solvents, a series of tests were done on basic refined paraffin wax. Table III summarizes the relative value of a number of solvents. Diesel was used as base indicator because of its ready availability. The total solubility after 24 hours for xylene and toluene was less than 40% higher than diesel but the delivered cost of these solvents can be 200-300% greater in some areas. These results should not be extrapolated for use with all paraffins. There are some paraffins that may have significant amounts of asphaltenes that may result in 24 hour aromatic solubilities that are 500-600% greater than diesel. The versatility of the aromatics is also one of the reasons for the industry bias that favors their use. This basic solubility test of various solvents should be done for specific paraffins to optimize the treating cost effectiveness.

SOLVENT PUMPING SCHEDULES

The total amount of solvent to be used to dissolve the paraffin should be based on actual solubility information and estimates of the total amount of paraffin in the well. For example, one particular well was estimated to take approximately 6 bbl of diesel to dissolve approximately 2000' of paraffin. The entire 6 barrels was not pumped at once because of the legacy of prior hot oiling. During the conversion from hot oiling to solvent treating, the residual buildup of paraffin in the annulus from repeated treatments is a concern. Using too much solvent too quickly could lead to fouled pumps from debris stripped off the tubing in the annulus. Contact time is also a concern that should favor smaller, more frequent treatments until a systematic schedule is developed. Several days after pumping the treatment, the flow line union should be broken out and the inspected for paraffin. This visual inspection is the most definitive test to determine the solvent schedule.

LOGISTICS ISSUES

Hot oilers generally do not haul solvents over the highways. Bulk chemical providers generally do not allow their drivers to connect to wells. Chemical treating companies generally do not have equipment configurations that accommodate small solvent treatments. Collectively, these issues led to a standalone trailer configuration to accommodate solvent treating. This trailer system needs to be located a safe distance from the well and should be properly grounded to the wellhead before pumping. After pumping, the equipment should not be disconnected until any static from pumping operations is dissipated. For larger jobs, drivers with CDLs with hazmat endorsements will be required.

ACCOUNTING ISSUES

Unlike hot oil treatments that use lease crude before it is sold, solvent treatments have some practical business issues that need to be addressed. First, since the solvents are hydrocarbons that will be sold with the crude oil, the volumes can be netted from the final sales so that royalties are not paid on the solvent that did not come from the mineral estate. These records should be maintained in the event of an audit. Second, budgeting for the treatments needs to be considered. If the gross cost of the solvent is charged to the budget of field superintendents and the sale of the solvent is not credited to the same budget, the paraffin treating budget will be dramatically overstated.

COST BENEFIT ANALYSIS

Although individual solvent job costs may be higher than annular hot oiling job costs, this simplistic comparison is meaningless if hot oiling is proven to be incapable of treating at sufficient depths. The potential of ineffective paraffin treating:

INCREASED ARTIFICIAL LIFT REPAIR COSTS

The continued buildup of paraffin below the shallow "apparent success" depth will lead to dramatically increased artificial lift repair costs. The increased drag of paraffin can result in rod parts, rod fishing costs, and stripping jobs. The buildup of paraffin in the annulus above the tubing anchors adds other risks to the analysis.

FORMATION DAMAGE

For situations with high melting point paraffins and low formation temperatures, the formation damage risks of annular hot oiling can be dramatically more than the mechanical risks.

SAFETY

Hot oiling is generally accepted to be one of the most hazardous operations in field operations. Every year there are a number of fires and/or deaths related to fire tube failures or the ignition of hydrocarbons.

EMISSIONS

Emissions from hot oiling come from burning propane to heat the lease crude and from the lighter components of lease crude that are vaporized while the crude is being heated.

CONCLUSIONS

Solvent treating is more effective than annular hot oiling at removing paraffin in the artificial lift system. When the associated costs of failing to treat for paraffin are considered, the cost effectiveness of solvent treating can be dramatic. Before starting a solvent program, basic testing of field paraffin with potential solvents need to be performed to optimize the treatment.

REFERENCES

Mansure, A.J. and Barker, K.M., "Practical Hot Oiling and Hot Watering for Paraffin Control", SPE Operations Symposium, March 1993. (Part of this work was performed by Sandia National Laboratories for the United States Department of Energy under contract DE-AC04-94AL85000)

Mansure, A.J., "Hot Oiling Spreadsheet", Sandia National Laboratories, Sand96-2247 UC-122, 1996 (part of Sandia National Laboratories contract with the Department of Energy under contract DE-AC04-76DP00789)

Copeland, Carter, et el, Hot Oiling Effective Treating Depth, 59th Annual Southwestern Petroleum Short Course, April 18-19, 2012.

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Table I-Field Paraffin Melting Temperatures

Depth	Depth	Melting Temperature (F)	Formation Temperature (F)	Comments
A	5000	175	125	Severe formation risk
B	8600	176	165	Potential formation risk
C	8600	151	165	Minimal formation risk

Table II – Annular hot oiling job profiles (3 well average)

Burner temperature (F)	Pumping Tee Temperature (F)
224	**181**

(Pumping Tee temperature immediately after annular pumping ceases)

Table III – Solvent cost effectiveness
Food Grade Paraffin
80F, 344 g samples

Solvent	24 hour dissolution (%)	24 hour solubility relative to Diesel (%)
Diesel	71	100
Xylene	96	135
Toluene	90	127