A NOVEL TECHNIQUE FOR AVOIDING PARAFFIN PROBLEMS - A FIELD STUDY IN THE ACKERLY DEAN UNIT, DAWSON COUNTY, TEXAS

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ABSTRACT

Paraffin formation has been a problem for many oil producers. Current technology for alleviating the problem of paraffin build up consists of: (1) mechanical removal, (2) removal with hot oil or other solvents, and (3) treating the wellbore with a paraffin dispersant or inhibitor. This paper will discuss the application of a new form of paraffin inhibitor and a novel technique for introducing the paraffin inhibitor into the producing formation. The study was conducted in the Dean Formation, Ackerly Dean Unit (ADU), Dawson County, Texas.

INTRODUCTION

Paraffin is a constituent of most crude oils found in the United States. A study of crudes from 69 different oil fields in 19 states showed that paraffin was present in oil from 59 fields in 18 of the states.[1] Paraffin or wax is composed of long-chain alkanes with the general formula C_nH_{2n+2}. The number of carbon atoms present may range from 20 (melting point of 98° F) to 60 (melting point of 215° F).

Paraffin forms in the oil production system as two types of wax crystals. Paraffin wax (which constitutes 40 - 60% of the deposits found) consists of large well-formed needle-shaped crystals which agglomerate to form large masses. The second type is a microcrystalline wax that has many side branches off the main carbon chain, and forms small irregular crystals with little tendency to agglomerate.[1]

Paraffin or wax precipitation can accumulate in any part of production equipment, e.g., downhole pumps and rods, surface flow lines, and storage tanks. The wax accumulation may initiate well problems with downhole equipment as well as surface equipment. All these problems translate to less oil produced and lower profits.

Paraffin formation was first studied in the early 1930's.[2,3,4] The solubility of paraffin in crude oil depends on the chemical composition of the crude, and the temperature and pressure of the production system. Paraffin will begin to crystallize in oil as soon as the equilibrium temperature and pressure, i.e., the cloud point, is attained. At equilibrium, the wax crystals form and are redissolved until nucleation occurs. Nucleation is defined as the point where the crystallization rate exceeds the rate of solution, thus allowing the wax crystals to agglomerate into large masses that may plug production equipment.[1,5,6] The paraffin mass may form in perforations, on pumps, rods, in flow lines and other surface equipment or can build up in the oil increasing the oil's viscosity and reducing production rates.

The average yearly expenditures for paraffin control in domestic production was estimated to be in excess of 20 million dollars. This figure represents the direct cost for periodic removal of paraffin by mechanical, thermal and chemical means. The estimate does not include provisions for lost production, increased horsepower requirements, damage or increased wear on equipment and manpower required. Operators have a choice between philosophies for coping with paraffin: (1) wait until paraffin deposits and then remove it, or (2) prevent the formation of paraffin by introducing an inhibitor into the system. Economics of each individual field will ultimately dictate which philosophy is applied.

This paper will discuss a novel approach to the problem of paraffin control in crudes from the Dean formation, Ackerly Dean Unit (ADU), Dawson County, Texas (see Figure 1). The approach combines the addition of a paraffin inhibitor to fracture stimulation treatments. The successful treatment yields a fractured well that produces without problems related to paraffin deposition for a net 4 to 6 months, thus providing the operator time to evaluate the economics and choose between a mechanical removal system and chemical treatment program.

GEOLOGY

The Dean formation in the Ackerly Dean Unit (ADU) is a Permian Age rock which formed a stratigraphic trap that is westward-dipping regional homocline. The Dean sand was first observed in Gulf Oil's Dean #1 at approximately 8,000 feet in Dawson County, Texas. The pay is about 200 feet thick consisting of 125 feet of coarse grain gray and brown sandstone and 75 feet of siltstone with stringers of gray dense limestone and gray to black shales. The shale is normally found in the form of thin partings separating relatively clean, thin beds of sand. The Dean was deposited as a series of prograding submarine sands, however, the beds or lenses of sand are regarded as lithologic rather than time units. In general, the permeability and porosity of the Dean range from 0.3 - 1 md. and 7 - 11%, respectively, based on core and log evaluations.

The Dean sand is considered a highly fractured system that depends on the fracture channels as well as the matrix porosity for production. Flow rates in the Dean, calculated with the normal radial flow equations and no natural fractures for a 40 foot section, are in the 5 - 10 bpd range. If natural fractures are assumed present, the productive sand face area is increased 120 - 150 times.

ANALYSIS OF THE DEAN CRUDE

Samples of oil were obtained from several sections of the unit for analysis (see Table 1). The crude examined had API gravities in the 37° - 38° range. Paraffin and asphaltene concentrations ranged from 6 - 8% and from 0 - 0.5% by weight, respectively. The pour point was found to be less than -40° F. Paraffin deposition was found from the surface to approximately 3600 feet. The average well, not treated with a paraffin inhibitor, produced for an average of 130 days without some type of paraffin-related well problem (see Table 2).

COMPLETION HISTORY

Both openhole and casedhole completions were employed in the ADU. In openhole completions, 4½ or 5½ inch casing was set at the top of the Dean formation, leaving approximately 180 feet of open hole. Casedhole completions used 5½ inch casing and were perforated via casing with one (0.35 inch) shot per net foot of pay.

The Dean formation typically requires some type of acid breakdown before the zone can be evaluated. Therefore, 500 - 2500 gallons of 15% HCl containing a surfactant and an iron sequesterant was pumped to assist in formation breakdown. Ball sealers were added to the casedhole breakdown jobs in an effort to ball out the well. The spent acid was flowed or swabbed back and the zone evaluated.

All of the Dean wells in the ADU required some type of additional stimulation, namely, hydraulic fracturing. ADU frac treatments varied from 22,000 - 82,000 gallons of fluid and 30,000 - 180,000 pounds of 20/40 mesh sand (see Table 3). The fluid used was a 2% potassium chloride-based crosslinked 40 pound hydroxypropyl guar (HPG) system that contained a 5% diesel phase as a fluid loss additive, surfactants, a clay stabilizer, and a gel breaker. Wells were fractured via casing at injection rates ranging from 20 - 40 bpm at surface treating pressures of 1400 - 4700 psi (see Table 3).

NOVEL TECHNIQUE FOR PARAFFIN CONTROL

As noted earlier, operators can significantly reduce the deposition of paraffin in downhole equipment, tubular goods, and surface lines by using deposition inhibitors. These chemicals are similar in molecular form to the paraffin which deposits from the produced oil or condensate, which allows them to combine with the paraffin particles or crystals. This union of the inhibitor with the paraffin will change the paraffin slightly. In many instances, this slight alteration of the crystal growth pattern is sufficient to: (1) reduce the tendency for paraffin agglomeration, (2) reduce the tendency for paraffin deposition, and (3) reduce the observed pour point of the oil or condensate containing the inhibitor.

The key properties which determine how effective these treatment chemicals will be, are the solubility of the chemical in the oil or condensate and structure of the chemical. Since the inhibitor must be incorporated into the crystal network of the paraffin in order for it to be effective, the inhibitor should have solubility characteristics similar to the paraffinic hydrocarbons which tend to deposit. Yet, the structure of the inhibitor chemical must be different enough from the paraffin to modify the paraffin's crystal growth.

As previously mentioned, this novel technique for paraffin control involves the addition of a crystal growth modifier (an inhibitor) to a fracture stimulation treatment. The paraffin inhibitor is added to the treatment in both a liquid and a solid form. The liquid form immediately begins modifying the paraffin crystals while the solid form (approximately 10 mesh in size) slowly dissolves, thus maintaining a sufficient concentration of inhibitor to control paraffin deposition for an extended period of time.

Initially, the commercially available ethylene-vinyl acetate crystal modifier (Chemical A) was added as the inhibitor. The liquid phase was added at 5 gallons/1000 gallons in the pad stage and then reduced to 1 gallon/1000 gallons in the sand-laden stage. The solid form was added at 10 pounds/1000 gallons in the sand-laden fluid. Chemical A was included in the treatment of Wells 1608 and 1804 (see Table 4).

A second paraffin inhibitor (Chemical B) was also investigated. Chemical B is a proprietary product that contains a blend of laboratory-proven paraffin inhibitors. These inhibitors, before being formulated into their long-lasting (solid) form, were tested with crude oils from a variety of formations. The apparatus shown in Figure 2 was used to determine paraffin inhibitor efficiency.

In a typical evaluation, six beakers containing crude oil with various loadings of inhibitors are warmed in a water bath to a temperature above the cloud point of the crude. The contents of the beakers are continuously agitated with a six-paddle stirrer. A water-based fluid, at temperatures slightly below the cloud point, is passed through a string of stainless steel U-tubes, on which paraffin may deposit. After approximately 1 - 2 grams of paraffin builds up on the reference U-tube (no inhibitor in the crude), the test is completed (6 - 10 hours). The U-tubes are placed in preweighed beakers and placed in an oven at 170° F. The efficiency of the paraffin inhibitor is calculated by the reduction in recovered paraffin as compared with the deposit recovered from the reference U-tube. Results of several tests using the blend of inhibitor chosen for the proprietary product, Chemical B, are shown in Table 5. Examination of the "Δ Deposit" column yields an average reduction in deposition of approximately 52% over a range of 28 to 76% for the eleven crudes tested. This uncommon versatility of Chemical B is attributed to the blend of inhibitors that compose Chemical B.

Initially, through a trial-and-error process, an inhibitor loading of 100 - 300 ppm was determined to give a 50% reduction of paraffin deposit when compared with the reference sample. As the laboratory study of inhibitors continued, determinations of the type shown in Table 6 were performed for each crude oil of interest. In the case of the ADU 1202 sample, approximately 200 - 250 ppm was required to reduce paraffin deposition by a factor of two. The next step in the process was to apply these inhibitors in a controlled-release form to give long-term deposition protection to wells in the Ackerly Dean Unit.

Chemical B was included in the fracture treatments of two wells, the 2203 and the 3203R (see Table 4). The loading of Chemical B was the same as that of Chemical A: 5 gallons/1000 gallons liquid in the pad and 1 gallon/1000 gallons liquid in the sand-laden fluid, and 10 pounds/1000 gallons of the solid in the sand-laden fluid.

Recall for the paraffin treatment to be considered a success, well treated with inhibitor must produce 4 to 6 months longer than wells without a paraffin inhibitor. Wells 1608 and 1804 have met the criterion producing problem free for a net 148 and 127 days respectively. Wells 2203 and 3203R are quickly approaching the net 120 day mark, each producing problem free 107 and 76 days respectively. (A production history up-date will be given at the oral presentation in April, 1984.)

ECONOMICS

A study of the economics of adding a paraffin inhibitor to a fracturing fluid was conducted to determine the cost-effectiveness of the treatment. The average daily cost for remedial paraffin deposition control was computed for a year by examining the average cost incurred per remedial treatment and the frequency of the treatments for the wells (shown on Table 2) fractured without a paraffin inhibitor. The projected average daily cost for remedial paraffin control was $4.17 per day or $1,522 per year (see Figure 3).

Initially, the projected daily cost for the addition of a paraffin inhibitor to a fracturing treatment is approximately the same as the yearly cost of a remedial treatment, $1,100 (see Figure 3). However, after about 160 days the paraffin inhibitor costs drop below the remedial treatment costs, such that over a projected one year period the use of a paraffin inhibitor to control deposition becomes an economic success.

CONCLUSIONS

1. Paraffin deposition can be controlled for a net 4 to 6 months by including a paraffin inhibitor to a fracturing treatment.

2. The addition of a paraffin inhibitor to a fracturing treatment is a one-time treatment. After an extended period of time, some other type of paraffin deposition control and/or removal is required.

3. The inclusion of a paraffin inhibitor chemical is projected to be cost effective over a one year period.

4. Care should be taken to choose the best inhibitor or blend of inhibitors for the crude oil to be treated.

5. Laboratory studies may be employed to assist in the determination of the proper inhibitor concentration required to provide 4 to 6 months of protection.

6. Future studies should include more rigorous monitoring of paraffin deposition by monitoring tubing and flow line pressures.

7. Future studies should include a method for monitoring paraffin inhibitor concentrations in the crude oil to assist in the evaluation of the inhibitor deposition protection over a period of time.

NOMENCLATURE

STP - Surface Treating Pressure
ISIP - Instantanious Shut-In Pressure

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Table 1
Analysis of Crude Oil from Dean Formation
Ackerly Dean Unit, Dawson County, Texas

Well No.	Depth (ft)	° API*	% Paraffin	% Asphaltene	Pour Point ° F
2001	8650	37	8	0	-40
1201	8700	38	6	0.5	-40
2303	8750	38	7.5	0	-40

* Corrected to 60° F

Table 2
Production History without Paraffin Control

Well No.	Date Stimulated	Date of First Paraffin Problem	Time Produced (Days)
502	01-30-83	04-01-83	60
602	06-17-82	09-13-82	88
702	05-14-82	05-24-82	10
703	08-12-82	10-18-82	67
1403	07-10-82	04-05-83	269
1508	04-22-82	03-05-83	317
1703	12-28-82	04-05-83	98
		Average	130

Table 3
Review of Fracture Treatments for the Dean Formation, Ackerly Dean Unit, Dawson County, Texas

Well No.	Depth (ft)	Fluid Vol. (gal)	20/40 Sand (lbs)	Rate (bpm)	STP (psi)	ISIP (psi)
502	8698-8718	60,000	85,000	20	2,800	1,110
602	8650-8771	82,000	168,000	32	2,150	--
702	8720-8806	40,000	115,000	30	2,500	1,900
703	8760-8853	60,000	180,000	40	2,800	1,550
1403	8731-8832	50,000	115,000	40	2,500	1,800
1508	8616-8680	60,000	174,000	31	2,800	1,800
1608	8686-8754	27,000	41,000	39	3,923	1,800
1703	8664-8850	22,000	30,000	40	2,400	--
1804	8754-8844	75,000	115,000	40	3,000	1,250
2203	8713-8762	75,000	115,000	38	4,700	1,600
3203R	8606-8688	75,000	115,000	40	3,650	1,500

Table 4
Production History with Paraffin Control

Well No.	Inhibitor Used	Date Stimulated	Date of First Paraffin Problem	Time Produced (days)
1608	Chemical A	05-27-83	Present	278
1804	Chemical A	06-17-83	Present	257
2203	Chemical B	07-07-83	Present	237
3203R	Chemical B	08-08-83	Present	206
			Average	245

Table 5
Inhibition Performance Test

Formation (API Gravity @ 60° F)	% Paraffin	% Asphaltene	Ref. Sample Deposit, g	Sample Treated with Chemical B Deposit, g	Sample Treated with Chemical B △ Deposit [a]
Marmaton (37.6°)	15	1	0.96	0.57	41%
Spraberry (35.8°)	7	<1	1.31	0.46	65%
Cherokee (34.8°)	15	2	1.02	0.58	43%
Mississippian (35.2°)	9	2	0.79	0.57	28%
Penrose (33.6°)	7	10	1.69	0.63	63%
Premier Sand (32.6°)	5	11	1.53	0.51	67%
Red Fork (43.6°)	21	1	1.73	0.53	69%
Red Fork (43.6°)	21	1	1.60	1.03 [b]	36%
Dean (38.6°)	8	<1	0.92	0.61	34%
Glorieta (36.6°)	7	<1	0.79	0.19	76%
Dean (38.0°)	6	<1	0.68	0.30 [b]	56%

[a] Performance/Effectiveness (△ Deposit) is quantified in laboratory tests by comparing the paraffin deposition in a treated sample to that observed in an untreated reference sample:

$$\frac{\text{Deposit (ref.) - Deposit (treated)}}{\text{Deposit (ref.)}} \times 100$$

[b] A 250 ppm loading of inhibitor was used; other tests were conducted with 300 ppm.

Table 6
Inhibitor Effectiveness Profile Test Using Chemical B

Formation	Inhibitor Loading, PPM (Paraffin Deposit, g)					
Red Fork	0 (1.68)	50 (1.50)	100 (1.49)	250 (1.03)	500 (0.57)	1000 (0.15)
Dean (ADU 1202)	0 (0.68)	50 (0.77)	100 (0.54)	250 (0.30)	500 (0.13)	1000 (0.18)
Red Valley & 2nd Venango	0 (1.73)	-	100 (0.59)	250 (0.44)	500 (0.28)	-

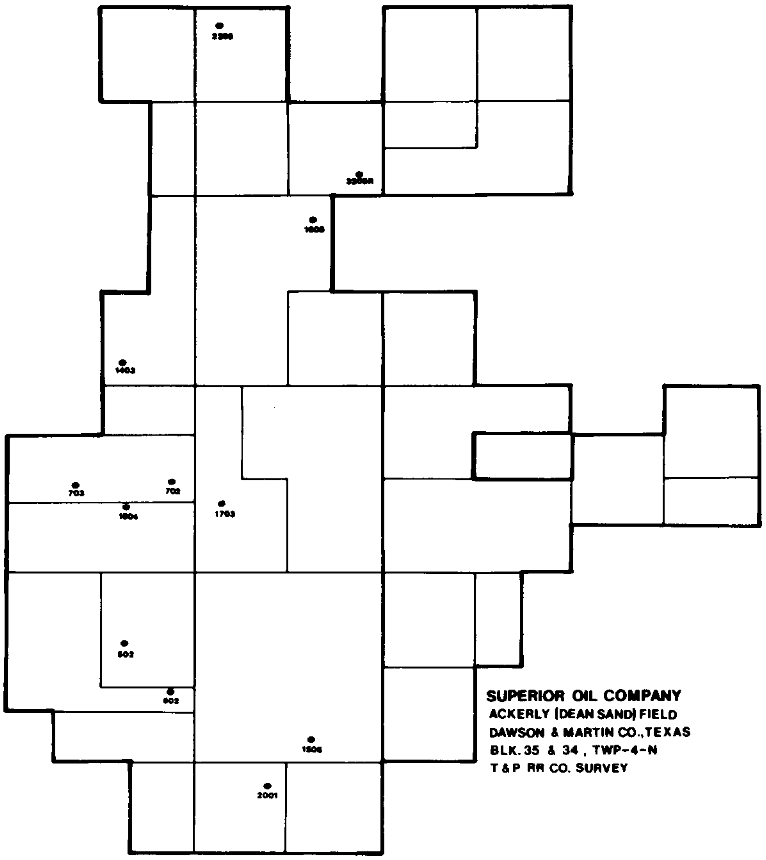

Figure 1 - Overview of Ackerly Dean Field, Dawson County, Texas

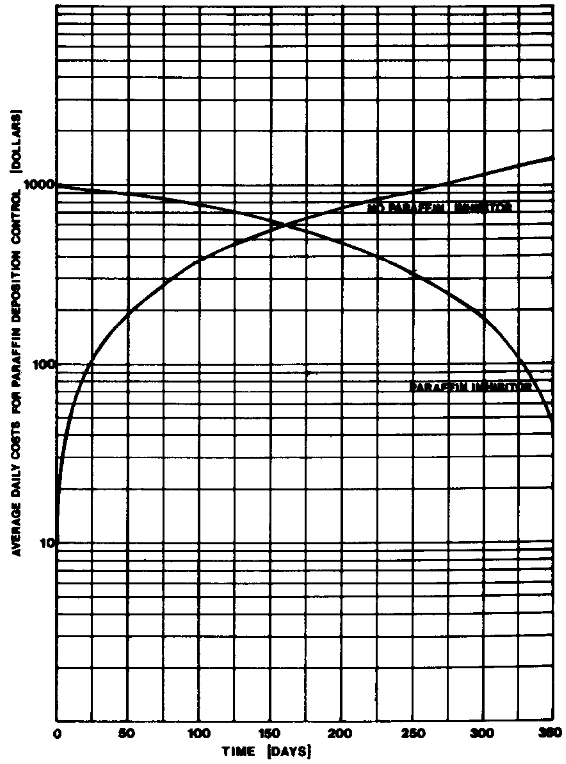

Figure 3 - Plot of average daily costs for paraffin deposition control vs. time

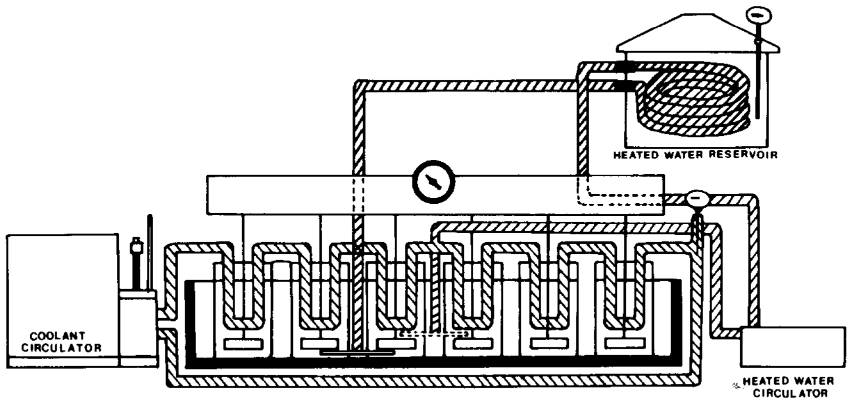

Figure 2 - Laboratory apparatus used to determine paraffin inhibitor efficiency