AN EXPERIMENTAL PARAFFIN CONTROL TREATMENT PROCEDURE

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An experimental paraffin control technique has been developed and tested in several West Texas Chevron operated leases producing from the Spraberry formation. The results were encouraging. The methods described below provide a structured framework for testing and analyzing paraffin control and for applying the procedures developed.

The economics of the program were generally favorable. The average savings per well compared with hot oiling during the approximate one year testing period were $460 and $320 on the Test Leases No.3 and No.1, respectively. This compares favorably to the usual cost of hot oiling which ranged from $135 to $180 per well every month or two.

A number of unexpected results occurred during the testing period. The production of a number of the wells actually increased after treatment and some decreased after normal hot oiling was resumed. This will be discussed further in the text of this paper.

It was recognized by the field foreman that the current method of paraffin control in several of his fields, hot oiling, was both expensive and could lead to other problems such as formation damage. This presented an incentive for him to attempt to improve paraffin control procedures in these fields.

As a result of this investigation, a systematic squeeze treatment procedure was developed which showed promise in reducing the hot oiling requirements on the three test leases. A total of forty-two paraffin problem wells were treated over a two year period. It was more than a year before it was necessary to re-initiate regular hot oilings on the group of treated wells in order to maintain production.

The economics of the program were based on reduction in hot oiling compared to the cost of the treatment. The costs of the treatments were subtracted from the reduced expense of not hot oiling the test wells for the life of the treatment. Even using conservative measures the treatments saved approximately $8000 over the actual lifetimes of the squeezes on the group of test wells compared with the regular hot oiling program. The summary savings by lease are:

Lease	per Lease	per Well
Test Lease No.1	$640	$320
*Test Lease No.2	($3227)	($215)
Test Lease No.3	$11500	$460

* Most of the wells on the Test Lease No.2 were still performing

satisfactorily along their normal decline curves when they were hot oiled and the test on this lease aborted. This is shown in the attached production data. Had they been allowed to continue at least two months longer then the program on this lease would have shown a positive cash flow.

GENERAL REASONS TO REDUCE HOT OILING FREQUENCY ON THE SUBJECT SPRABERRY LEASES

As recognized by the production foreman of these three West Texas Chevron operated leases and shown by current literature there are many reasons to avoid or reduce hot oiling.

As has been pointed out in the industry for years and summarized in a recent SPE paper "Hot oiling is so readily accepted that formation damage may not be associated with the hot oiling process." (reference #1) The hot oiling systematically concentrates the higher molecular weight paraffins in the wellbore and even reintroduces them into the formation. It is at the formation face and in the formation that hot oiling cycles build up a deposit of paraffin over time that is not removed by subsequent hot oilings.

In the defense of hot oiling, this has been the only practical method of removing enough of the paraffin build-up at the formation face of the subject Spraberry leases that they could produce on an acceptable decline curve.

The practice of regularly hot oiling Spraberry wells to control production loss due to paraffin deposition can seem excessive to some not familiar with Spraberry production. When these leases were placed under the previous production foreman hot oiling was severely curtailed as being excessive. As the decline curve accelerated, hot oiling was once again resumed. The source of the hot oiling feed has been the stock tanks on the leases to be hot oiled. It has been shown that hot oiling with this same oil concentrates the paraffin that the formation face is exposed to and is one of the causes of unremoved paraffin build up over time. (reference #1)

As this oil is heated to very high temperatures of 300°-320°F, some oil on the order of 1-10 weight percent is lost to evaporation. This not only concentrates the paraffins in the oil, but first lost are the lighter ends which serve to help keep the paraffins in suspension. (reference #1)

When hot oil is pumped down a well a large amount of heat loss occurs before the oil reaches the bottom of the well. Heat is lost to the oil in the production tubing as the well is being pumped during the hot oiling and to the formation outside of the casing. When the oil does reach the bottom of the well it is much cooler than when it was pumped.

The oil arriving at the bottom of the formation contains not only the concentrated paraffins from the stock tank but also any paraffin that it may have melted falling down the annulus. From recent studies of paraffins in crude oil it appears that a controlling factor in the deposition process appears to be the cloud point and paraffin content.(reference #3)

The paraffin content of the oil at the formation face of the test wells fits this criteria by both having a higher concentration of paraffin and a lower cloud point by having the lighter ends evaporated through the process of heating the oil during hot oiling . The oil at the bottom of the well at this point has higher paraffin forming tendencies than the oil normally produced.

It has been shown by fluid level testing that the subject leases generally have very low bottom hole pressures. As the result of this, hot oil first arriving at the bottom of the well is at a higher pressure than the formation due to hydrostatic pressure. The higher pressure hot oil invades the formation carrying with it high concentrations of paraffin. Some of this reintroduced paraffin may remain in the formation presenting an ever tougher removal problem for subsequent hot oilings.

From the results of many of the test wells and the summary of results by field it appears that this formation invasion by a high paraffin content, depressed cloud point oil over the years has caused some formation damage. Many of the test wells actually showed an increase in production after squeeze treatment and a decrease in production after normal monthly hot oiling was resumed. This is seen most dramatically in the summary graph of the No.3 Lease test wells.

Alternatives to using lease crude for hot oiling such as kerosine or diesel treatments, are and continue to be cost prohibitive. Another common alternative to using lease crude in many applications is hot water. Due to the nature of the paraffin in these test leases hot watering is also not a viable alternative.

Hot water in contact with this particular high molecular weight paraffin dries it out and reduces it to a very hard material similar in look, texture, and hardness to the popular canning material known as Gulf Wax.

One other factor was a driving force in finding alternatives to continuous hot oiling. That was casing expansion during hot oiling. Many of the wells on the Test Lease No.3 did not have cement circulated past a corrosive water zone behind the long string. Monthly expansion and contraction of the long string due to hot oiling could only weaken the casing exposed to this zone much as one would break a wire by continuous flexing. This unit has experienced numerous casing leaks in the past and it was desired to avoid any future ones if at all possible.

ORIGINAL TESTING

With an understanding of the possible formation damage occuring from repeated hot oilings, a search was made for a possible squeeze process to replace hot oilings. The philosophy was simple but effective. If a promising treatment could be identified it would be applied to a few wells to judge effectiveness. If results appeared positive then the process would be expanded to four more wells. If results were still positive then it would be expanded to much more comprehensive field testing.

To begin the study, there were investigations of various products for possible well treatment use. There are several categories of products which exhibit different effects on paraffin; these include:

1. Paraffin Inhibitors - Sometimes called crystal modifiers, this is a group of chemicals which alter the formation of paraffin crystal growth. (reference #2) At that time there was no practical way of introducing these high molecular weight copolymers into the formation other than during a fracture treatment. Other paraffin products are in a liquid form and may easily be pumped into a well at normal temperatures.

2. Paraffin Dispersants - These chemically coat the paraffin molecules and help reduce their depositional tendencies.

3. Detergents - This is the basic action of a soap. A chemical which has both an oil soluble end and a water soluble end. This molecule attaches to the paraffin molecule and allows it to be "washed" out with warm water.(reference #5)

4. Solvents - Actually dissolve portions of the paraffin wax depending upon the paraffin molecular weight and the well pressure and temperature. (reference #2)

After reviewing several compounds, one showed a promising reduction of the pour point of Test Lease No.3 crude. The chosen product was a dispersant. This crude did indeed have paraffin deposition characteristics as show by a cloud point of 48°F and a C-18 and greater content of between 9-14% (depending on sample well).

In June, 1983 the Test Lease No.3 wells #618 and #619 were chosen for testing. One drum of test chemical was mixed with 25 barrels of lease crude and flushed with 150 barrels of produced water down the annulus at a controlled pumping rate not exceeding 2.5 BPM. The well was closed in for 24 hours to allow the chemical to soak on the formation. The results were considered effective as neither well was hot oiled for over a year while maintaining a reasonable production decline. A plot of both the first and second squeeze results of these wells is found in the attached plots.

The flush volume chosen was the annular capacity of these wells (150 barrels) and has proven to be an effective flush volume for scale inhibition squeezes which were regularly done on Test Lease No.3.

At the same time another test of the technique was performed on Test Lease No.2 well #29 but, with a variation. The difference was that it was applied after the well had been treated for scale and paraffin removal with a 1000 gallon 15% HCL and Xylene treatment. The paraffin chemical was also pumped in conjunction with a scale inhibitor chemical using again 150 barrels flush. The combination treatment was effective for approximately a year as is shown in this well's plot in the plot section.

The variation of treating the well for scale before squeezing for paraffin is the next logical step of exploration as all of the subject leases have scale forming tendencies. The initial success of the first application of this variation has promise as just the paraffin treatment alone has shown effective.

EXPANDED TESTING

After the initial tests proved successful, four more Lease No.3 wells were selected for testing: 203, 702, 1112, And 1506. After eight months the results were still positive. After a review of the preliminary results and based upon the fact that approximately half of one lease's production was used in the monthly hot oiling program, management approval was given for an expanded testing program.

Twenty more Lease No.3 Unit wells, the two Lease No.1 wells, and sixteen Lease No.2 wells were targeted for paraffin squeezes. The technique used on the Test Lease No.3 remained the same. The squeeze procedure on the other two test leases again included a scale inhibitor chemical.

Part of the reason for including a scale inhibitor chemical with the squeeze job was the fact that over $40,000 had just been spent on one of the Test Lease No.1 wells related to a scale problem. A piece of casing was attached to the tubing anchor compounded by the fact that the pump was cemented in place by scale.

DISCUSSION OF THE RESULTS OF THE EXPANDED TEST

To evaluate the paraffin squeeze program, an answer was needed for the question "Did the squeeze life expense offset the expense of the hot oilings that would have occurred to keep the production on a normal decline curve ?"

In order to answer this question, production data for all the test wells was compiled before the squeeze was done, during the life of the squeeze, and after normal hot oilings were reinstituted. This production data was input into a personal computer and analyzed using basic statistical routines.

A dilemma was overcome by using basic statistics to help answering how long the squeeze life lasted. The decline curves of most wells are routinely determined by arbitrarily drawing a line through the plotted production data. It was realized with the number of wells involved in the test program that several different people could determine an almost infinite variety of declines. To help remove personal bias from the system, a regression line was fitted through the pre-squeeze data, squeeze life data, and hot oiling resumed data.

For the regression fits to the experimental data, it was decided to use a linear fit as opposed to a logarithmic fit. The test fields were in the latter stages of production which is almost linear as approximated by the latter portions of the exponential decay curve. A linear fit also helped overcome the mathematically poor fit a non-linear technique would have had with the large month to month fluctuations that many of the wells exhibited.

The regression lines so produced had a good fit in many cases as observed in the plots and also from their correlation coefficients. Even though some fits were poor they all still provided unbiased indicators of the production trends of the wells.

Regression lines from the pre-squeeze phase were extended into the squeeze phase and the squeeze phase regression lines were extended into the squeeze life phase in each well's production plot. These were used to judge when the squeeze life decline fell below what would have been expected under the established hot oiling routines.

From this analysis it appears that 20 out of the 25 (80%) Test Lease No.3 squeezes were successful and both of the Test Lease No.1 squeezes were also successful. Carrying the extra expense of a scale squeeze the average shortfall of the Test Lease No.2 wells was $215. However, it can be seen from the analyzed plots that returning most of these wells to normal hot oiling was premature with 80% of these wells still remaining above the hot oiling predicted decline curves.

If the majority of the Test Lease No.2 wells had been allowed to produce for two more months without hot oiling, this lease's project would have also had a positive cash flow paying for the scale squeezes in addition to the paraffin squeezes. Also supporting this is the summary of the average test well's production during the squeeze life compared to the time immediately after the test in which hot oiling was resumed.

For this time immediately after the test on the No.2 Lease was terminated that there was no production increase after hot oiling was resumed. This also supports the squeeze life of the No.2 Lease was longer than just the arbitrary termination date of nine months.

The results of the Test Lease No.1 were the most dramatic. As seen in the accompanying plots the production from these two wells increased markedly after treatment.

The summary plot for Lease No.3 also showed unexpected results. After treatment, the average test well experienced increasing production for five months to reach two barrels a day above the pre-treatment level. It also showed a decline after hot oiling resumed for an average loss of four barrels a day at the end of five months. This is significant in that the production tended to rise on the test wells while hot oiling was substituted for and fall after hot oiling was reinitiated.

Supporting data for the preceding results and following recommendations are found in the accompanying tables and graphs.

RECOMMENDATIONS

As the program shows a substantial positive effect upon production while reducing the frequency of needed hot oiling, it should be expanded. The present method need not be used alone as demonstrated in Test Lease No.2 Well 29 early in the program. There the paraffin squeeze followed a treatment designed to remove scale.

All three leases have shown very high scaling tendencies. It would be counterproductive to treat for paraffin while ignoring scale or the other way around. In future treatments it was recommended that the well be treated for scale removal before the paraffin treatment is applied.

New paraffin technologies have evolved since the inception of this program. These should not be ignored in that they may enhance the techniques demonstrated here. One such technology which was not available in 1983, as previously stated. This technique is to actually precipitate a paraffin inhibitor in the formation by use of an "activator". This is demonstrated in an SPE paper presented in Oklahoma City in 1987.(reference #4) It should be tested whether using such a technique after the formation has been cleaned of paraffin buildup can significantly extend the squeeze life of these wells.

The exact reasons why this technique shows success in reducing the need for hot oiling has not been resolved. One deduction from observing the extremely clean tubulars of some of the test wells may be because the seed crystals that paraffin would form around are effectively removed. This approach consisted of basic steps which could be applied in any field in which hot oiling must be used to control paraffin:

1. Decide if the expense of hot oiling is large enough to justify possible alternative treatment or if there is evidence of formation damage from repeated hot oilings that is considered excessive.

2.Test various products for their effect upon the paraffin forming characteristics of the subject crude and their compatibility with the formation fluids.

3.Select one product for testing and design a treatment procedure. Also select one or more wells as test candidates which should be representative of the field.

4.Clean the test wells up as much as is practical with a good clean up system and remove scale if there is evidence of same.

5.Apply the test method to the test well(s).

6.Monitor the production of the well. Prepare decline curves of the test well(s) and post each test to this decline curve. This way the monthly results of the test can be evaluated by seeing if the production falls on the decline line or below each month. Use judgement to determine when the effects of the treatment have stopped and paraffin is again causing a significant production drop. It is recommended to use statistical curve fitting to minimize bias effects.

7.Evaluate the success of the test upon the monetary effect of not exceeding the cost of the regular hot oiling minus the cost of the treatment for the time period involved.

8.If the preliminary tests show promise, expand the treatments to a larger test group.

9.If secondary testing is also encouraging, then expand to comprehensive testing.

10.Be flexible in the application technique in order to incorporate any promising modifications in the method or chemical used. This is illustrated by a promising paraffin control chemical being introduced at the end of this test program. This particular chemical offers the promise of actually precipitating in the formation by use of an "activator", and slowly dissolving as the oil is produced. (Reference #4)

REFERENCES:

1.Barker, K.M.: "Formation Damage Related to Hot Oiling", SPE 16230, SPE Production Operations Symposium, Oklahoma City, Oklahoma, March 8-11, 1987.

2.Barker, K.M. and Newberry, M.E.: "Formation Damage Prevention Through the Control of Paraffin and Asphaltene Deposition", SPE 13796, SPE Production Operations Symposium, Oklahoma City, Oklahoma, March 10-12, 1985.

3. Gdanski, Rick: "Paraffin Problems in Low Paraffin Content Crude", Southwestern Petroleum Short Course Proceedings(April, 1974),449-456.

4. Haynes, H.H. and Lenderman, G.L.: "Cost-Effective Paraffin Inhibitor Squeezes Can Improve Production Economics", SPE 15178, Rocky Mountain Regional Meeting of the Society of Petroleum Engineers held in Billings, MT, May 19-21, 1986.

5. McCall, James M., Jr.: "Paraffin Treatment in the Well Service Industry ", Southwestern Petroleum Short Course Proceedings(April, 1974), 457-464.

Table of Squeeze Results by Field and Well

TEST LEASE NO.2:

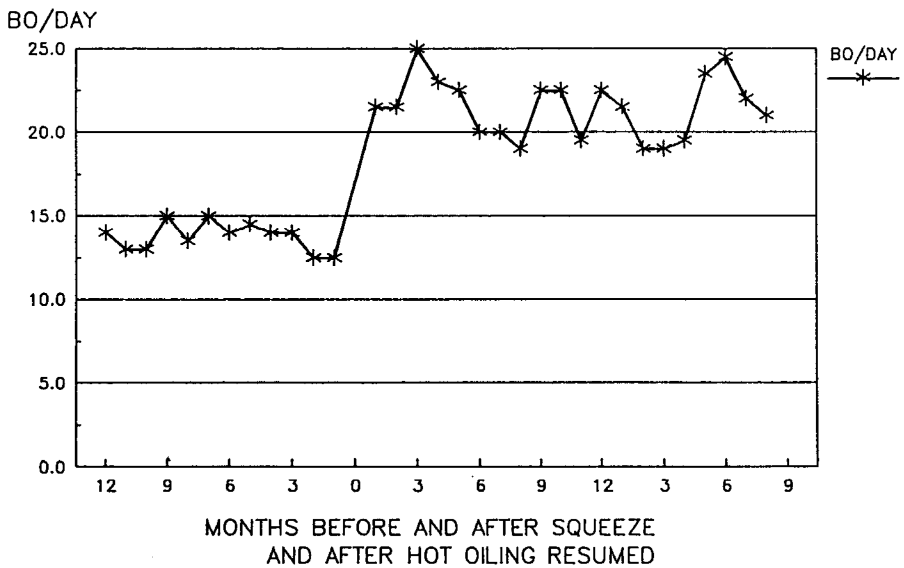
Well	Hot Oiling Oiling Frequency Before Squeeze	Decline Slope Better After Squeeze?	Slope Worse After Hot Oiling Resumed?	Min. Sqz. Life	Slope Better or as Good After Squeeze?	Slope Look Worse After Hot Oiling?
1.	12/14	No	No	9	Yes	Same, fall after 5 Mos.
4.	13/14	Yes	Yes	9	Yes - Incr for 9 Mos.	Yes, fall Immediately
5.	11/14	Yes	No	9	Yes- Slightly Better	No- Slightly Better for 8 Mos.
7.	12/14	No	No	9	About Same	Same
10.	14/14	No	No	3	Fall after 3	No
11.	12/14	Yes	No	9	About Same	Same
13.	14/14	No	Yes	9	Slightly Better	Same
16.	13/14	Yes	Neutral	9	Fall to 1 BOPD	Same
18.	14/14	Yes	Yes	9	Has Declined to 1-2 BOPD	Same
21.	14/14	Same	No	9	Level @2-3 BOPD Just as Before	Same for 6 Mos. then 1 BOPD Incr.
22.	14/14	No	No	6	Slight Decline 5-6 BOPD	Decline Same
31.	13/14	No	No	4	Sharp Drop to 3 BOPD after 4 Mos.	Level
34.	13/14	No	No	9	Somewhat Less But at Decline Lvl	Approx. Same
35.	14/14	No	No	9	Incr. After 4 Mos.	Approx. Same
36.	14/14	Yes	Yes	9	Stabilized	Stabilized

TEST LEASE NO.3:

Well	Hot Oiling Oiling Frequency Before Squeeze	Decline Slope Better After Squeeze?	Slope Worse After Hot Oiling Resumed?	Min. Sqz. Life	Slope Better or as Good After Squeeze?	Slope Look Worse After Hot Oiling?
202	12/13	Yes	Yes	11	Yes	Nuetral - Later Declines
203	8/8	Yes	Yes	12+	Mixed	Yes
205	12/13	Yes	No	12	Yes	Yes - for 6 Mos
206	12/13	Yes	Yes	8	Yes	Yes
208	9/13	No	No	Unsuccessful		
301	11/13	No	SI	7	Yes	
503	12/13	No	Yes	6	Yes	Yes
614	12/13	Yes	Yes	11	Yes	Yes
618		Yes	Yes	13	Yes	About Same
618s		No				
619		Yes	Yes			
619s		Yes	Yes			
624	12/13	Yes	No	12	Yes	Yes
625	11/13	No	Yes	11	Yes	Yes
702	11/11	Yes	Yes	This production was increasing due to apparent waterflood response - disqualified		
801	11/13	Yes	Yes	16	Yes	Yes
902	11/13	Yes	Not H.O.!	10	Yes	
903	10/13	Yes	Yes	14	Yes	Yes
1006	13/13					
1101	11/13	Yes	Not H.O.!	14	Yes	
1112	7/7	No	No	8	About Same	Yes - for 6 Mos
1116	12/13	No	Unsuccessful			
1117	13/13	Yes	Yes	9	Yes	Yes
1506	4/8	Yes	No	8	Yes	Not for 3 Mos.
1706	7/11	No	No			
1910	7/13	Yes	No	12	Yes	No

TEST LEASE NO. 1

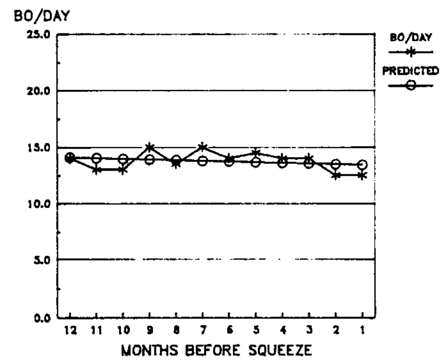
AVERAGE TEST WELL PRODUCTION DURING:
PRE–SQUEEZE, POST SQUEEZE, & RESUME HOT OILING



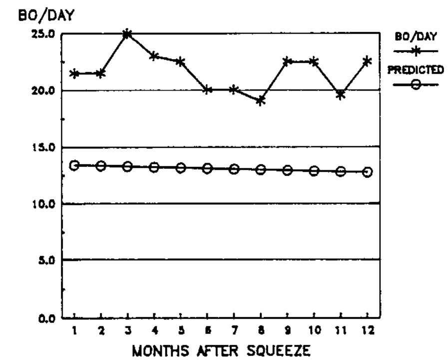
TEST LEASE NO.1

COMPARISON OF AVERAGE TEST WELL PERFORMANCE

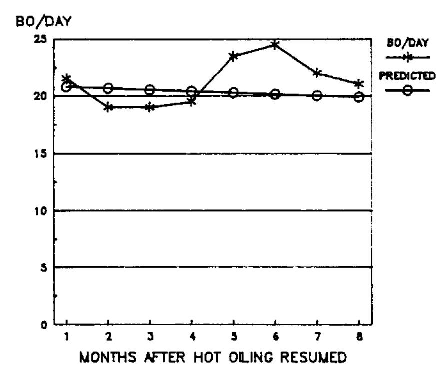
BEFORE SQUEEZE



SQUEEZE LIFE
WITH PRE-SQUEEZE TREND OVERLAID



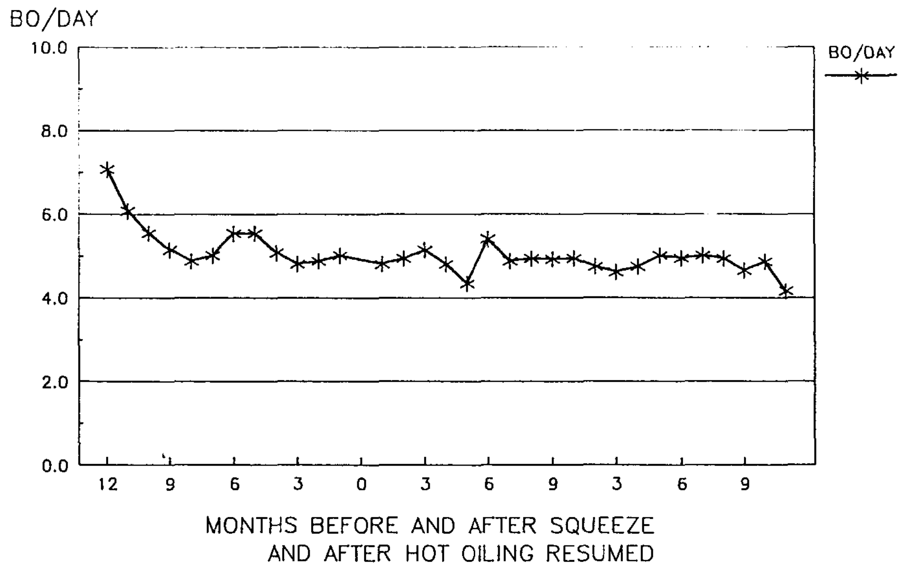
HOT OILING RESUMED
WITH SQUEEZE TREND OVERLAID



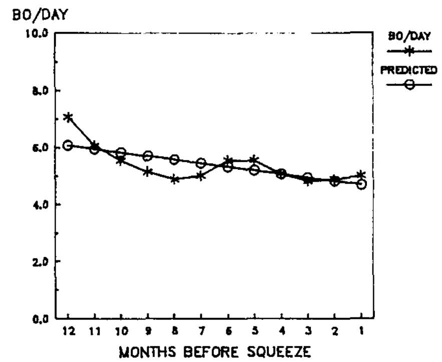
TEST LEASE NO. 2
FIELD AVERAGE RESULTS

TEST LEASE NO.2

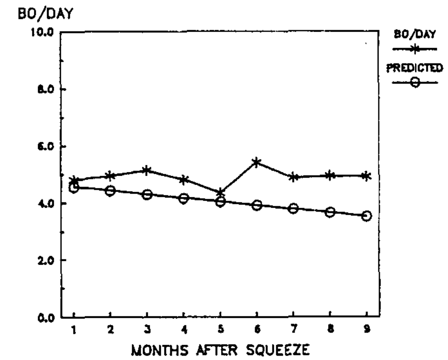
AVERAGE TEST WELL PRODUCTION TREND DURING:
PRE-SQUEEZE, POST-SQUEEZE, & RESUME HOT OILING



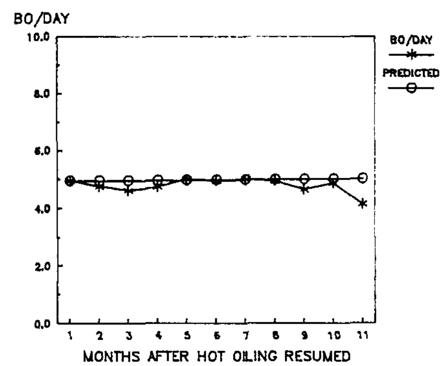
BEFORE SQUEEZE



SQUEEZE LIFE
WITH PRE-SQUEEZE TREND OVERLAID

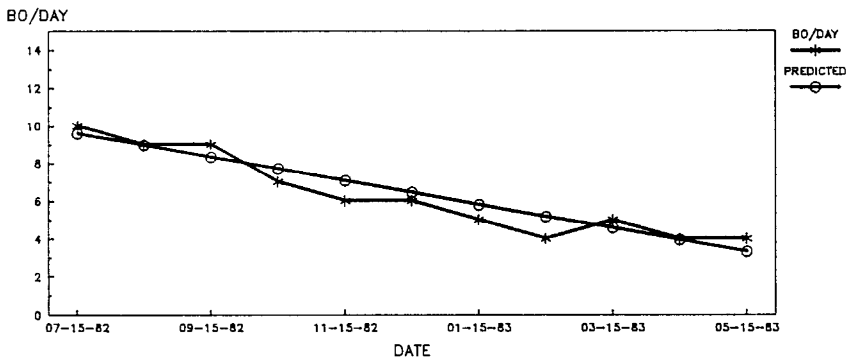


RESUME HOT OILING
WITH SQUEEZE TREND OVERLAID

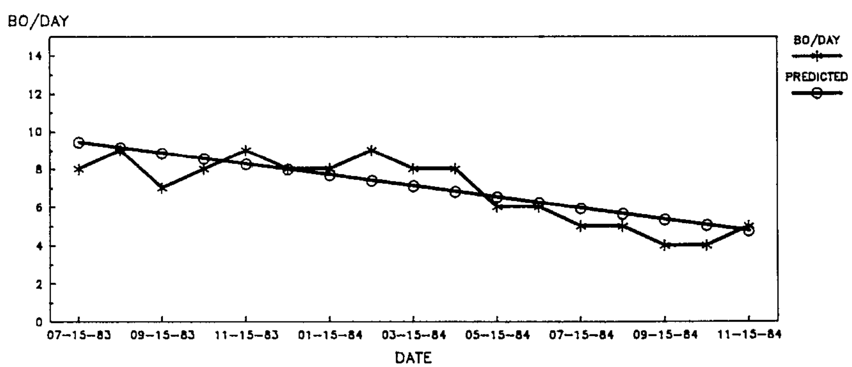


TEST LEASE NO.2 - WELL 29
EXAMPLE OF AN ACID JOB FOLLOWED W/SQUEEZE

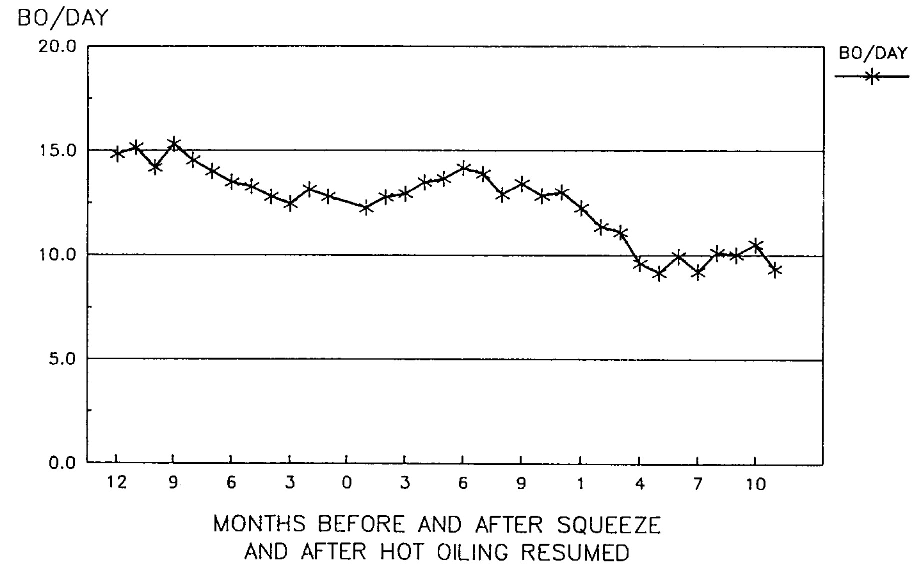
PRODUCTION BEFORE
5/83 ACID JOB AND 6/83 PARAFFIN SQUEEZE



PRODUCTION FOLLOWING
5/83 ACID JOB AND 6/83 PARAFFIN SQUEEZE

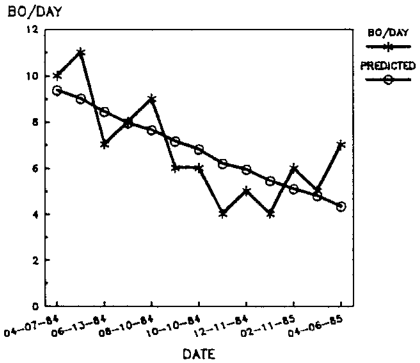


TEST LEASE NO.3
AVERAGE TEST WELL PRODUCTION TREND DURING:
PRE-SQUEEZE, POST SQUEEZE, & RESUME HOT OILING

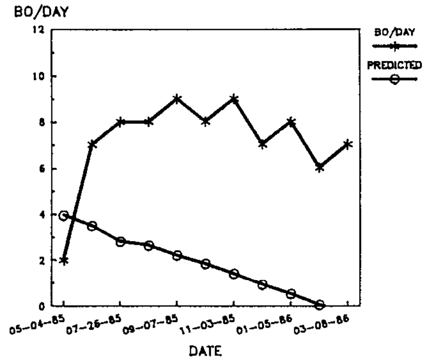


TEST LEASE NO.3 - WELL 614

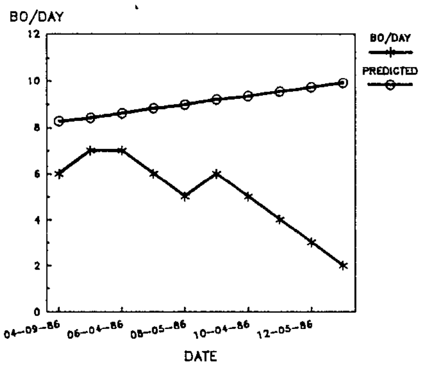
BEFORE SQUEEZE



SQUEEZE LIFE
WITH PRE-SQUEEZE TREND OVERLAID



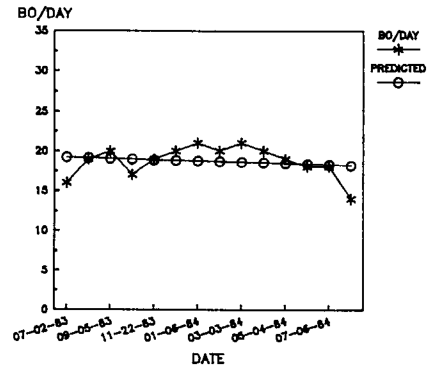
RESUME HOT OILING
WITH SQUEEZE TREND OVERLAID



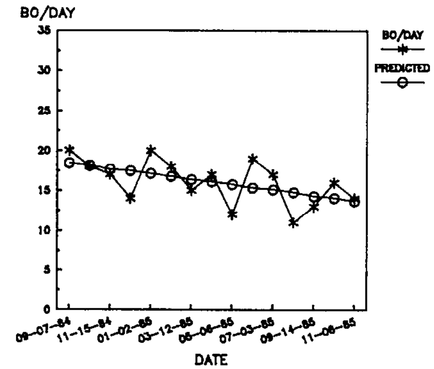
TEST LEASE NO.3 - WELL 618

COMPARISON OF 1ST AND 2ND SQUEEZES

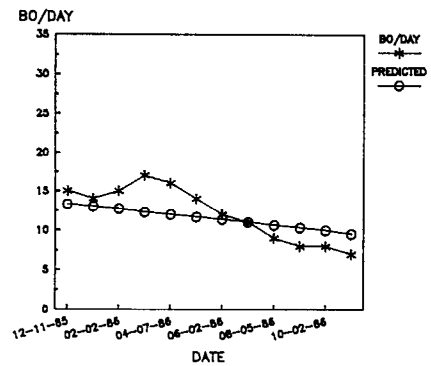
1ST SQUEEZE LIFE
WITH REGRESSION LINE OVERLAID



BETWEEN 1ST AND 2ND SQUEEZES
HOT OILING RESUMED
REGRESSION LINE OVERLAID

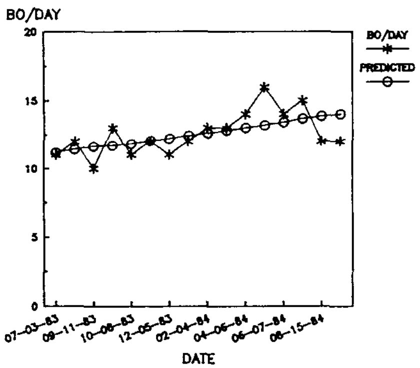


2ND SQUEEZE LIFE
WITH PRE-SQUEEZE TREND OVERLAID
NOT HOT OILED UNTIL 11/87

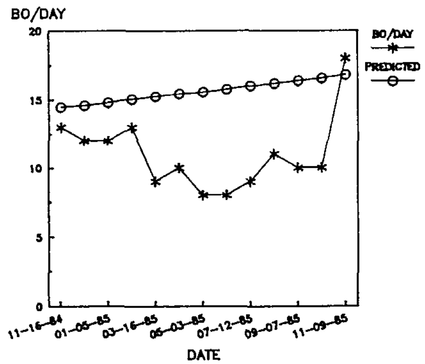


TEST LEASE NO.3 – WELL 619
COMPARISON OF 1ST AND 2ND SQUEEZE

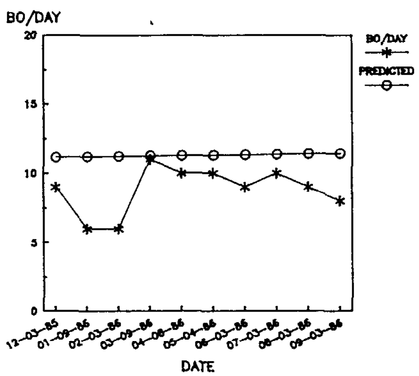
DURING SQUEEZE LIFE
WITH REGRESSION LINE OVERLAID



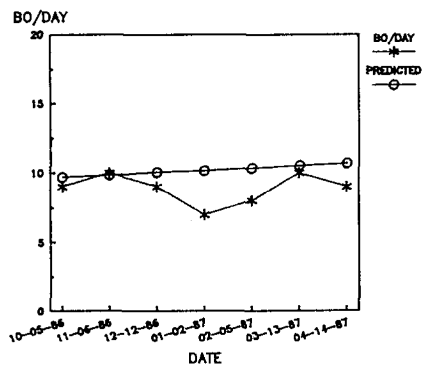
RESUME HOT OILING
WITH SQUEEZE TREND OVERLAID



SECOND SQUEEZE LIFE
WITH PRE-SQUEEZE LINE OVERLAID

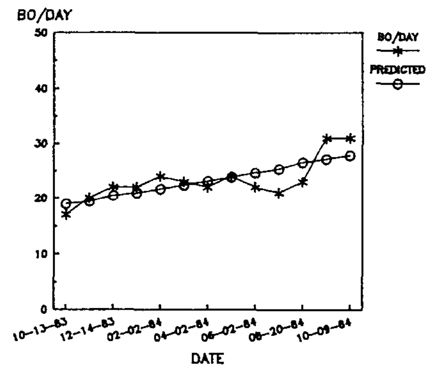


RESUME HOT OILING
WITH SECOND SQUEEZE TREND OVERLAID

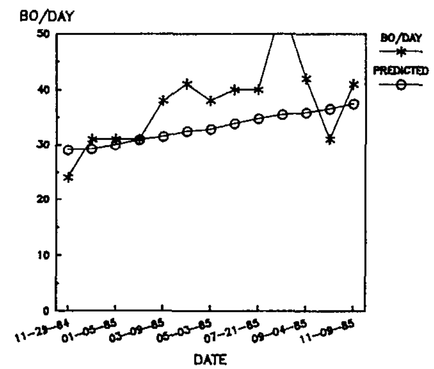


TEST LEASE NO.3 – WELL 702
WATERFLOOD RESPONSE

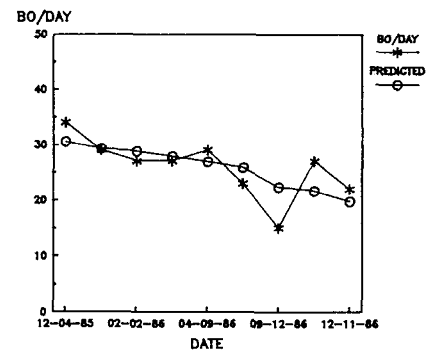
BEFORE SQUEEZE



1ST SQUEEZE LIFE
WITH PRE-SQUEEZE TREND OVERLAID

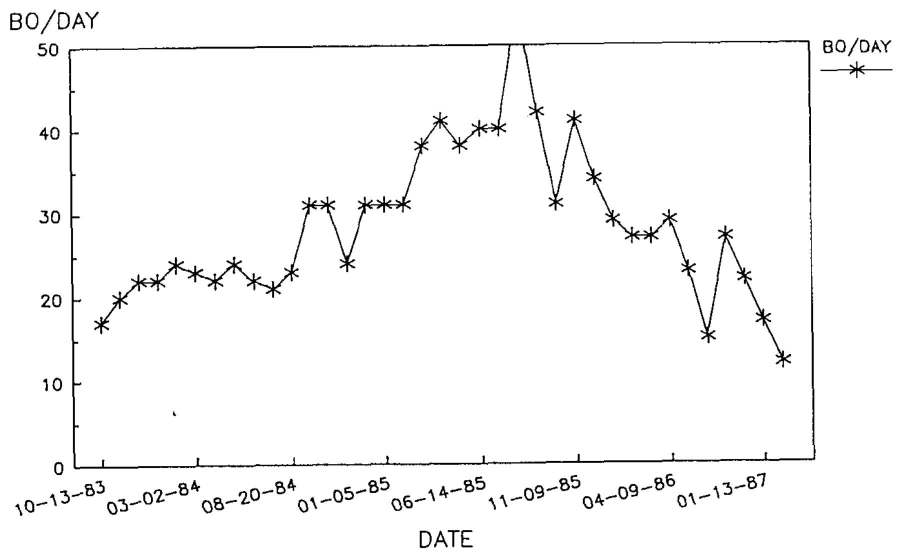


SECOND SQUEEZE LIFE
REGRESSION LINE OVERLAID

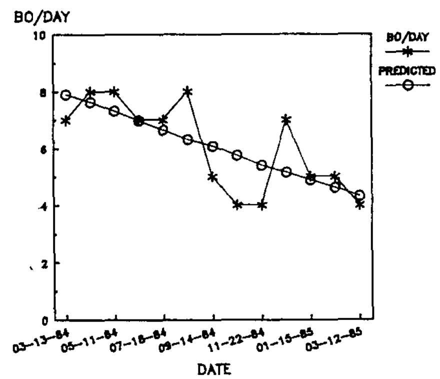


TEST LEASE NO.3 - WELL 903

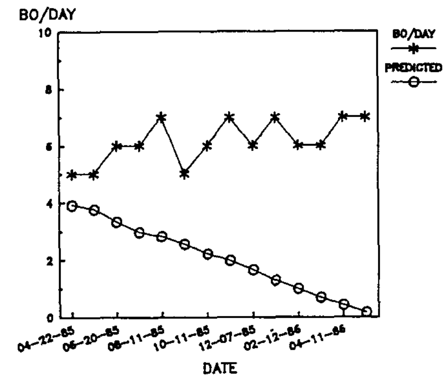
TEST LEASE NO.3 - WELL 702
SQUEEZE EFFECT MASKED BY WATERFLOOD RESPONSE



BEFORE SQUEEZE



SQUEEZE LIFE
WITH PRE-SQUEEZE TREND OVERLAID



RESUME HOT OILING
WITH SQUEEZE TREND OVERLAID