SPE

Society of Petroleum Engineers

SPE 23813

Wellbore Stimulation Using Microorganisms To Control and Remediate Existing Paraffin Accumulations

J.W. Pelger, Bio Tech Inc.

SPE Member

This paper was prepared for presentation at the SPE Intl. Symposium on Formation Damage Control held in Lafayette, Louisiana, February 26-27, 1992.

ABSTRACT

This paper will explain and demonstrate a method to increase production in individual wells or fields with skin damage, due to paraffin accumulations, corrosion, emulsion and scale formation, utilizing an individual treatment design from a library of facultative anaerobic microorganisms.

These neutrally charged marine organisms, in a saline solution of nutrients, are naturally occurring, non-pathogenic, non-toxic, non-carcinogenic, non-combustible and require no permits from the Environmental Protection Agency for storage, transportation or disposal. Environmentally, these microorganisms are as safe as any product in our industry to control and reduce skin damage.

Paraffin, corrosion, emulsion and scale formation have resulted in significant economic losses, reducing profitability for producers and operators. The resulting skin damage can be controlled and reduced through proper treatment by locating microorganisms in the immediate formation, perforations, and in the case of most problem preventing restrictions in production streams or failures in lifting equipment. Traditional control methods for treatment involve implementing techniques such as hot oiling, paraffin cutting, chemical and condensate treatments. These techniques have been marginally successful, economically prohibitive and temporary at best. Many of these traditional methods are dangerous from a safety standpoint and often have caused serious long term damage to the productive life of the well (especially in the case of hot oiling).

References and tables at end of paper.

INTRODUCTION

Paraffin skin damage can either be naturally occurring or man-made due to repeated hot oil-hot water treatments down the annulus. Naturally occurring paraffin is due to a formation temperature lower than the cloud point of the fluids produced. Paraffins created by hot oil-hot water treatments can cause a large amount of skin damage due to the liquids burning off the lighter hydrocarbons and pushing the heavier ends, possibly pulled from the bottom of a stock tank, downhole. Both types of damage reduce the effective permeability and porosity at or near the formation face while a hot oil treatment can cause plugged perforations and restrictions in the wellbore.

Since the microorganisms thrive at the oil/water or water/paraffin contact, they will naturally seek out the paraffin skin damage and gradually remediate the high carbon chain paraffins with a cloud point above the formation temperature. This remediation process will gradually biodegrade the skin damage that is interfering with the natural inflow of fluids into the wellbore and control formation of paraffin accumulations in the production system.

Bio Tech, Inc. is monitoring ninety-one (91) wells throughout Oklahoma, since December of 1990, for an independent oil & gas operator. The information from these 91 wells has been collected and several case studies have been selected to show the advantages of microbial treatments to remediate existing skin damage, extend productivity, and increase profitability by reducing operating expenses.

MONITORED TREATMENT RESULTS

The 91 wells monitored have been separated into three regions: Eastern, Southern and Western. The percentage of wells where an increase in production occurred is listed in **Table 1**. Each region produces from multiple formations and depths. The Eastern region includes North East Canadian, Noble, Garfield and East Kingfisher counties and the perforated formations range from depths of 4,250 feet (Layton) to 8,830 feet (Viola). The Southern region includes South Canadian, Carter, Garvin, Grady, Love, McClain and Stephens counties with perforated formations ranging from depths of 5,240 feet (Goodwin) to 11,470 feet (Viola). The Western region includes Alfalfa, Blaine, Ellis, West Kingfisher, Major and Woodward counties with perforated formations ranging from depths of 5,880 feet (Hogshooter) to 10,650 feet (Hunton).

Table 1 figures show a dramatic percentage of the wells treated in each region encountered an increase in production of either oil, gas or a combination of oil and/or gas. The Southern region responded with the largest percentage of wells with an increase in oil (84.8%), gas (80.6%), or a combination of oil and/or gas (93.9%). The next region responding with the second largest percentage of wells increasing in production was the Eastern Region with oil (70.8%), gas (66.7%), or a combination of oil and/or gas (87.5%). This was followed by the Western Region which indicated apercentage of wells with increases of oil (76.5%), gas (60.6%), or a combination of oil and/or gas (85.5%). The water figures also indicate either a normal decline or a reduction of water produced in 82.4% of the wells treated.

The method used to determine a production increase or stabilization effect was done by monitoring the past several years to establish a base decline. Many of the wells production increased just by stabilizing the decline curve or slightly increasing the production just by avoiding downtime associated with well problems caused by chemical circulation times or rig work. However, many wells have seen a dramatic increase in production due to the bioremediation of wellbore restrictions, plugged perforations, formation damage and extending the pump life due to the reduction of wear-and-tear caused by paraffin accumulations.

PRELIMINARY TESTING AND DESIGN

Once the problem wells were identified, all pertinent well data, history, and wellhead fluid samples were sent to the lab and evaluated for "treatability" and any negative influences, induced or naturally occurring in the fluids. A treatability or compatibility rating and a microbial dosage is established to optimally control the identified problem on every well. Together with the well data and the history, an appropriate treatment was designed for each well to achieve the discussed goals of the project. The parameters that must be met for a microbial project are listed in **Table 2**.

MICROORGANISM CASE STUDIES

CASE STUDY NUMBER 1

WELL DATA

The J&P Robberson lease is located in Canadian County, W/2 NW of Section 14-T10N-R5W in the Mustang Field. The formation being produced is the Hunton at depths of 8,886 to 8,902 feet. This well was being treated monthly with 25 gallons of paraffin solvent and 10 gallons of paraffin dispersant; and it had to be hot oiled down the backside four times per year.

OBJECTIVE

Increase well profitability by reducing rig activity caused by paraffin and corrosion failures. Remediating the paraffin skin damage causing an accelerated production decline curve and controlling paraffin accumulations within the production system, stabilize the production decline curve, which will ultimately increase production by extending the wells' economic life. (**Figure 1** shows the decline curves due to the microbial activity.)

SAMPLING OF THE WELLBORE FLUIDS

The treatability of the fluids sampled was determined to be a 2+. The dosage was determined to be 50% Para-Bac, 25% Para-Bac X and 25% Para-Bac XX. **Table 3** shows the recorded information since microbial treatment started on this well.

TREATMENT PROCEDURE

Initially this well was batch treated and shut in 24 hours to allow the water level and the microorganisms the opportunity to establish a colony over the perforated intervals. Then the well is shut in overnight after each treatment to supplement the microbial colonies to maintain a sufficient presence. This static condition allows the microorganisms the chance to start to remediate existing paraffin skin damage at the perforations, formation face and within the wellbore.

ECONOMICS

PREVIOUS OPERATING COSTS: .
25 gallons paraffin solvent +10 gallons paraffin dispersant = $262.50/month
Hot oil down backside 4 times per year @ $576.00/ea. = $2,204.00/year or $183.67/month

MICROBIAL OPERATING COSTS:
$393.30 (initial month) + $172.50 (15 months) = $2,980.80/year or $186.30/month

INCREMENTAL PRODUCTION
36.5 BOPM Increase (15 months)
($20.00/bbl) = $10,950.00/year or $730.00/month

SUMMARY OF ECONOMICS
(262.50) 15 + 186.67 (15) - (186.30) 15 + 730.00
(15) = $14,893.05 or $992.87/month

CASE STUDY NUMBER 2

WELL DATA

The Rigdon lease is located in Kingfisher County, N.E. Section 11-17N5W, in the Sooner Trend Field. The formations produced from are the Hunton, Mississippi and the Oswego at depths from 6,032 to 7,140 feet. This well was being treated with 15 gallons of paraffin dispersant and 1 drum of Xylene and the well had been pulled 12 times in the past 6 years for paraffin or corrosion problems. (See **Table 4**)

OBJECTIVE

Increase well productivity by reducing rig activity caused by paraffin and corrosion formation. Remediating the paraffin skin damage causing an accelerated production decline curve and controlling paraffin accumulations within the production system, stabilize the production decline curve, which will ultimately increase production by extending the wells' economic life.

SAMPLING OF THE WELLBORE FLUIDS

The treatability of the fluids sampled was determined to be a 2+. The dosage was determined to be 25% Para-Bac, 25% Para-Bac X, 25% Para-Bac XX and 25% Para-Bac XXX. **Table 5** shows the recorded information since microbial treatment started on this well.

TREATMENT PROCEDURE

Initially this well was batch treated and shut in 24 hours to allow the water level and the microorganisms the opportunity to establish a colony over the perforated intervals. Then the well is shut in overnight after each treatment to supplement the microbial colonies to maintain a sufficient presence. This static condition allows the microorganisms the chance to start to remediate existing paraffin skin damage at the perforations, formation face and within the wellbore.

ECONOMICS

Prior to microbial treatments, the well was being chemically batch treated down the backside with paraffin dispersant and Xylene. The well also averages two rig jobs per year over the past 6 years. **Figure 2** shows the decline curve and the natural bioremediation due to the microbial activity.

PREVIOUS OPERATING COSTS:

15 gallons paraffin dispersant + 55 gallons Xylene = $252.88/month

2 Rig jobs/year @ $6,000.00/job = $12,000.00/year or $1,000.00/month

MICROBIAL TREATMENT COSTS:

$310.50 (Initial month) + $131.10/month @ 11 months = $1,752.60 or $146.05/month

INCREMENTAL PRODUCTION:

26.1 BOPM (12 months) ($20.00 bbl.) = $6,264.00 or $522.00/month

107.5 MCFM (12 months) ($1.25/mcf) = $1,612.50 or $134.37/month

SUMMARY OF ECONOMICS:

252.88 (12) + 12,000.00 -1,752.60 + 6,264.00 + 1,612.50 = $21,158.46/year or $1,763.21/month

CASE STUDY NUMBER 3

WELL DATA

The J&P Schroeder lease is located in Grady County, E/2 N.E. of Section 23-T10N-R5W in the Mustang Field. The formation produced from is the Hunton at a depth of 8,746 to 8,772 feet. This well has been pulled four times in the past two years for tubing or casing leaks and a hot oil job would have to be performed to pull the well. (See **Table 6**)

OBJECTIVE

Increase well productivity by reducing rig activity caused by paraffin and corrosion formation. Remediating the paraffin skin damage causing an accelerated production decline curve and controlling paraffin accumulations within the production system, stabilize the production decline curve, which will ultimately increase production by extending the well' economic life.

SAMPLING OF THE WELLBORE FLUIDS

The treatability of the fluids sampled was determined to be a 3+. The dosage was determined to be 25% Para-Bac, 50% Para-Bac X, 25% Para-Bac XXX. **Table 7** shows the recorded information since microbial treatment started on this well.

TREATMENT PROCEDURE

Initially this well was batch treated and shut in 24 hours to allow the water level and the microorganisms the opportunity to establish a colony over the perforated intervals. Then the well is shut in overnight after each treatment to supplement the microbial colonies to maintain a sufficient presence. This static condition allows the microorganisms the chance to start to remediate existing paraffin skin damage at the perforations, formation face and within the wellbore.

ECONOMICS

Prior to microbial treatments, the well averaging 2 rig jobs per year and the well needed to be hot oiled to pull. (**Figure 3** shows the decline curves due to the microbial activity.)

PREVIOUS OPERATING COSTS:

2 Rig jobs/year @ $5,000.00/job = $10,000.00/year
or $833.00/month

Hot oiled when pulled @ $576.00/job x 2 = $1,152.00
or $96.00/month

MICROBIAL TREATMENT COSTS:

$703.80 (Initial month) + $269.10/month @
11 months = $3,663.90 or $305.32/month

INCREMENTAL PRODUCTION:

162.5 BOPM Increase ($20.00/Bbl.)
(12 months) = $39,000.00 or $3,250.00/month

325 MCFM (12 months) ($1.25/mcf) = $4,875.00
or $406.25/month

SUMMARY OF ECONOMICS:

10,000.00 + 96 (12) - 3,663.90 + 39,000.00 +
4,875.00 = $51,363.10 or $4,280.26/month

CASE STUDY NUMBER 4

WELL DATA

The FCD McGuire lease is located in Kingfisher County, S.E. Section 2-T17N-R5W in the Sooner Trend Field. The formations producing are the Skinner and Red Fork Sands at depths from 6,262 to 6,352 feet. This well had to be batch treated with 15 gallons of paraffin dispersant and 20 gallons of paraffin solvent monthly and circulated for 24 hours.

OBJECTIVE

Increase well profitability by reducing costs of existing chemical treatments. Remediate possible downhole skin damage to increase the productive live of the well.

SAMPLING OF THE WELLBORE FLUIDS

The treatability of the fluids sampled was determined to be a 3+. The dosage was determined to be 25% Para-Bac, 50% Para-Bac X, 25% Para-Bac XXX. **Table 8** shows the recorded information since microbial treatment started on this well.

TREATMENT PROCEDURE

Initially this well was batch treated and shut in 24 hours to allow the water level and the microorganisms the opportunity to establish a colony over the perforated intervals. Then the well is shut in overnight after each treatment to supplement the microbial colonies to maintain a sufficient presence. This static condition allows the microorganisms the chance to start to remediate existing paraffin skin damage at the perforations, formation face and within the wellbore.

ECONOMICS

Prior to microbial treatments, the well was being chemically batch treated down the backside with paraffin solvents and dispersants monthly and shut in 24 hours. **Figure 4** shows the decline curve.

PREVIOUS CHEMICAL COSTS:

15 gallons paraffin dispersant + 20 gallons
paraffin solvent = $2,240.00 or $186.67/month

MICROBIAL TREATMENT COSTS:

$351.90 (Initial month) + $151.80/month @
14 months = $2,477.10 or $165.14/month

INCREMENTAL PRODUCTION:
8.5 BOPM Increase ($20.00/Bbl.)
(15 months) = $2,550.00 or $212.50/month

346 MCFM (15 months) ($1.25/mcf) = $6,487.50
or $540.62/month

SUMMARY OF ECONOMICS:

186.67(15)-2,477.10+2,550.00+6,487.50=$9,360.45
or $624.03/month

RESULTS AND DISCUSSION FOR OPTIMUM WELLBORE TREATMENTS

Wellbore treatments using facultative anaerobic microorganisms to control and reduce paraffin formation are extremely cost effective. Bio Tech, Inc. treated 91 producing wells with this to control and reduce skin damage with 87.9% of the wells have realized control of the identified problems and increased the ultimate economic production life of the well. Individual wellbore treatments require less investment capital than previous techniques and the return on your investment is relatively short term. The procedural recommendations for optimal wellbore treatment techniques utilizing facultative anaerobic microorganisms must include:

1. Sampling of wellbore fluids to determine the treatability with microorganisms, including compatibility with well characteristics and the optimal inoculation percentages from the microbial library.

2. Treatment dosages designed specifically for individual wells. Initial and continued sampling of each well before and during treatment is highly recommended, whether treatment is to be rendered to the entire field or isolated wells. Although fields of wells, traditionally, have been thought to have similar rock matrices, fluids, etc.; individual dosage, presence and treatability tests have evidenced tremendous differences within the same field.

3. Well monitoring by the operator and service company for effective communication of changes in well operations. The operator must regularly monitor production for changes in the production stream. The service company must monitor microbial presence on a monthly basis, to accurately adjust dosage amounts and note hydrocarbon changes, yielding maximum productivity with minimum down-time and optimal cost efficiency. Complete and detailed well charting by the service company is integral to effective system monitoring.

CONCLUSIONS

1. The average Incremental Production per month on the 91 wells treated has been 2664 BOPM and 16,045 MCFM. Economically, the Incremental Production creates an increase in revenues by $53,280.00 per month for oil and $20,056.25 per month for gas.

2. Operating Costs have been reduced by 18.1% by eliminating chemical treatments, reducing hot oiling/watering of flowlines, wellbores and stock tanks and reduced mechanical cutting of paraffin from the wellbore. The time saved by field personnel by allowing them to mechanically repair surface equipment and free them of the responsibilities of following hot oilers or chemical treaters is not considered in the figure above.

3. Extending the economic production life of the treated wells by reducing the skin damage has increased the feasibility of producing these wells many more months/years. The average revenue made per month by using facultative anaerobic microorganisms has been $53,032.25 for the 91 wells tested.

NOMENCLATURE

P = Para-Bac:
Biodegrades Carbon Chain $C_{16}H_{34} \rightarrow C_{22}H_{46}$

Px = Para-Bac x:
Biodegrades Carbon Chain $C_{16}H_{34} \rightarrow C_{40}H_{82}$

Pxx = Para-Bac xx:
Biodegrades Carbon Chain $C_{40}H_{82} \rightarrow C_{60}H_{122}$

Pxxx = Para-Bac xxx:
Biodegrades Carbon Chain $C_{45}H_{92} \rightarrow C_{60}H_{122+}$

Ps = Para-Bac Super:
Biodegrades Carbon Chain $C_{16}H_{34} \rightarrow C_{70}H_{142+}$

The above microorganisms degrade the carbon chain two carbons at a time, enhancing the paraffin carrying capacity.

TT=Treatability (compatibility of microbes to fluids treated.)

Presence = Colonies per milliliter (optimum range: 800,000-1,200,000)

REFERENCES

Pelger, J.W., "Microbial Enhanced Oil Recovery Treatments and Wellbore Stimulation using Microorganisms to Control Paraffin, Emulsion, Corrosion, and Scale Formation," Microbial Enhancement of Oil Recovery - Recent Advances, edited by E.C. Donaldson, proceedings of the 1990 International Conference on Microbial Enhancement of Oil Recovery, 1991, pp. 451-466.

TABLE 1
Microbial Treatment Results

Region	Total Wells Treated	Treated Wells (Increase) Oil	(Increase) Gas	<Stabilize> Water	Percent Change (%) (Increase) Oil	(Increase) Gas	<Stabilize> Water	Oil/Gas
Eastern	24	(17)	(17)	<19>	(70.8)	(66.7)	<83.3>	(87.5)
Southern	33	(28)	(30)	<25>	(84.8)	(80.6)	<90.9>	(93.9)
Western	34	(26)	(28)	<20>	(76.5)	(60.6)	<82.4>	(85.5)
Totals:	91	(71)	(75)	<64>	(78.0)	(72.7)	<82.4>	(87.9)

TABLE 2
Parameters That Must Be Met For A Microbial Project

1. The survival temperature range is between 34° F-208° F. The microbes are dormant between 34° F-40° F.
2. The optimum temperature range is between 90° F-150° F. The microbes can multiply every 20-120 minutes at this temperature range.
3. The chloride content by volume needs to be less than 15%.
4. The pH needs to be greater than three (3).
5. The H2S content in a fluid needs to be less than 1000 ppm and 20,000 ppm in a gas.
6. The formation must produce at least a trace of water, or water must be added to provide the microorganisms with an adequate means of transportation throughout the entire system in the water phase.

TABLE 3
Microbial Treatment Information on the J&P Robberson Lease

Well Name	TT	BOPM BWPM MCFM	P	Px	Pxx	Pxxx	Presence	Total Gallons	5% KCL Flush	Treat Dates
Robberson	1+		2.9	1.4	1.4	0.0		5.7	28.5	08/27/90
		(See Figure 1)	0.6	0.6	1.3	0.0	NA	2.5	12.5	09/26/90
			0.6	0.6	1.3	0.0	700,000	2.5	12.5	10/24/90
			0.6	0.6	1.3	0.0	800,000	2.5	12.5	11/14/90
			0.6	0.6	1.3	0.0	NA	2.5	12.5	12/20/90
			0.6	0.6	1.3	0.0	No Wtr.	2.5	12.5	01/24/91
			0.6	0.6	1.3	0.0	1,300,000	2.5	12.5	02/21/91
			0.6	0.6	1.3	0.0	1,200,000	2.5	12.5	03/12/91
			0.6	0.6	1.3	0.0	700,000	2.5	12.5	04/16/91
			0.6	0.6	1.3	0.0	1,200,000	2.5	12.5	05/15/91
			0.6	0.6	1.3	0.0	700,000	2.5	12.5	06/14/91
			0.6	0.6	1.3	0.0	800,000	2.5	12.5	07/12/91
			0.6	0.6	1.3	0.0	700,000	2.5	12.5	08/15/91
			0.6	0.6	1.3	0.0	1,300,000	2.5	12.5	09/13/91
			0.6	0.6	1.3	0.0	800,000	2.5	12.5	10/22/91
			0.6	0.6	1.3	0.0	700,000	2.5	12.5	11/18/91

TABLE 4
Rig History Prior to Microbial Treatment in FCD Rigdon Lease

01/16/85	Tubing leak	Hot oil/pull to repair leak
02/06/85	Tubing leak	Hot oil/pull to repair leak
03/25/85	Tubing leak	Hot oil/pull to repair leak
01/31/86	Tubing leak	Hot oil/pull to repair leak
06/23/86	Rod part @ #121 joint	Hot oil/pull to repair rod
10/07/86	Pump change	Hot oil/pull to change pump
12/18/86	Rod part @ 7th joint	Hot oil/pull to repair rod
02/18/87	Pump change	Hot oil w/20 bbls to change
09/04/87	Pump change	Hot oil w/20 bbls to change
02/18/88	Pump chg/Excess Paraffin	Hot oil w/20 bbls to change
08/04/88	Tubing leak	Hot oil/pull to repair leak
02/01/89	Tubing leak	Hot oil w/24 bbls to repair

TABLE 5
Microbial Treatment Information on the FCD Rigdon Lease

Well Name	TT	BOPM BWPM MCFM	P	Px	Pxx	Pxxx	Presence	Total Gallons	5% KCL Flush	Treat Dates
FCD Rigdon	2+		1.1	1.2	1.1	1.1	NA	4.5	22.5	12/11/90
		(See Figure 2)	0.4	0.5	0.5	0.5	600,000	1.9	9.5	01/18/91
			0.4	0.5	0.5	0.5	900.000	1.9	9.5	02/11/91
			0.4	0.5	0.5	0.5	700,000	1.9	9.5	03/12/91
			0.6	0.6	1.3	0.0	900,000	2.5	12.5	04/08/91
			0.6	0.6	1.3	0.0	500,000	2.5	12.5	05/10/91
			0.6	0.6	1.3	0.0	1,400,000	2.5	12.5	06/12/91
			0.6	0.6	1.3	0.0	1,500,000	2.5	12.5	07/11/91
			0.6	0.6	1.3	0.0	900,000	2.5	12.5	08/13/91
			0.6	0.6	1.3	0.0	800,000	2.5	12.5	09/11/91
			0.6	0.6	1.3	0.0	1,200,000	2.5	12.5	10/15/91
			0.6	0.6	1.3	0.0	1,200,000	2.5	12.5	11/14/91

TABLE 6
Rig History Prior to Microbial Treatment on the J&P Schroeder Lease

March 1989	Tubing leak	Hot oil/pull to repair leak
November 1989	Tubing leak	Hot oil/pull to repair leak
June 1990	Casing leak	Hot oil/pull to repair leak
August 1990	Tubing leak	Hot oil/pull to repair leak

TABLE 7

Microbial Treatment Information on the J&P Schroeder Lease

Well Name	TT	BOPM BWPM MCFM	P	Px	Pxx	Pxxx	Ps	Presence	Total Gallons	5% KCL Flush	Treat Dates
Schroeder	3+		2.5	5.1	0.0	2.6	0.0	NA	10.2	51.0	12/20/90
		(See Figure 3)	1.0	1.9	0.0	1.0	0.0	800,000	3.9	19.5	01/24/91
			1.0	1.9	0.0	1.0	0.0	800,000	3.9	19.5	02/21/91
			1.0	1.9	0.0	1.0	0.0	NA	3.9	19.5	03/12/91
			1.0	1.9	0.0	1.0	0.0	900,000	3.9	19.5	04/16/91
			1.0	1.9	0.0	1.0	0.0	1,300,000	3.9	19.5	05/15/91
			0.0	0.0	0.0	0.0	3.9	1,100,000	3.9	19.5	06/14/91
			0.0	0.0	0.0	0.0	3.9	1,100,000	3.9	19.5	07/12/91
			0.0	0.0	0.0	0.0	3.9	700,000	3.9	19.5	08/15/91
			0.0	0.0	0.0	0.0	3.9	900,000	3.9	19.5	09/13/91
			0.0	0.0	0.0	0.0	3.9	900,000	3.9	19.5	10/22/91
			0.0	0.0	0.0	0.0	3.9	900,000	3.9	19.5	11/18/91

TABLE 8

Microbial Treatment Information on the FCD McGuire Lease

Well Name	TT	BOPM BWPM MCFM	P	Px	Pxx	Pxxx	Presence	Total Gallons	5% KCL Flush	Treat Dates
McGuire	3+		1.3	2.5	0.0	1.3	NA	2.5	25.5	09/10/90
		(See Figure 4)	0.5	1.1	0.0	0.6	1,000,000	2.2	11.0	10/11/90
			0.5	1.1	0.0	0.6	1,000,000	2.2	11.0	11/14/90
			0.5	1.1	0.0	0.6	No Wtr	2.2	11.0	12/11/90
			0.5	1.1	0.0	0.6	No Wtr	2.2	11.0	01/18/91
			0.5	1.1	0.0	0.6	No Wtr	2.2	11.0	02/11/91
			0.5	1.1	0.0	0.6	No Wtr	2.2	11.0	03/12/91
			0.5	1.1	0.0	0.6	No Wtr	2.2	11.0	04/08/91
			0.5	1.1	0.0	0.6	No Wtr	2.2	11.0	05/10/91
			0.5	1.1	0.0	0.6	700,000	2.2	11.0	06/12/91
			0.5	1.1	0.0	0.6	No Wtr	2.2	11.0	07/11/91
			0.5	1.1	0.0	0.6	No Wtr	2.2	11.0	08/13/91
			0.5	1.1	0.0	0.6	No Wtr	2.2	11.0	09/11/91
			0.5	1.1	0.0	0.6	No Wtr	2.2	11.0	10/15/91
			0.5	1.1	0.0	0.6	No Wtr	2.2	11.0	11/14/91

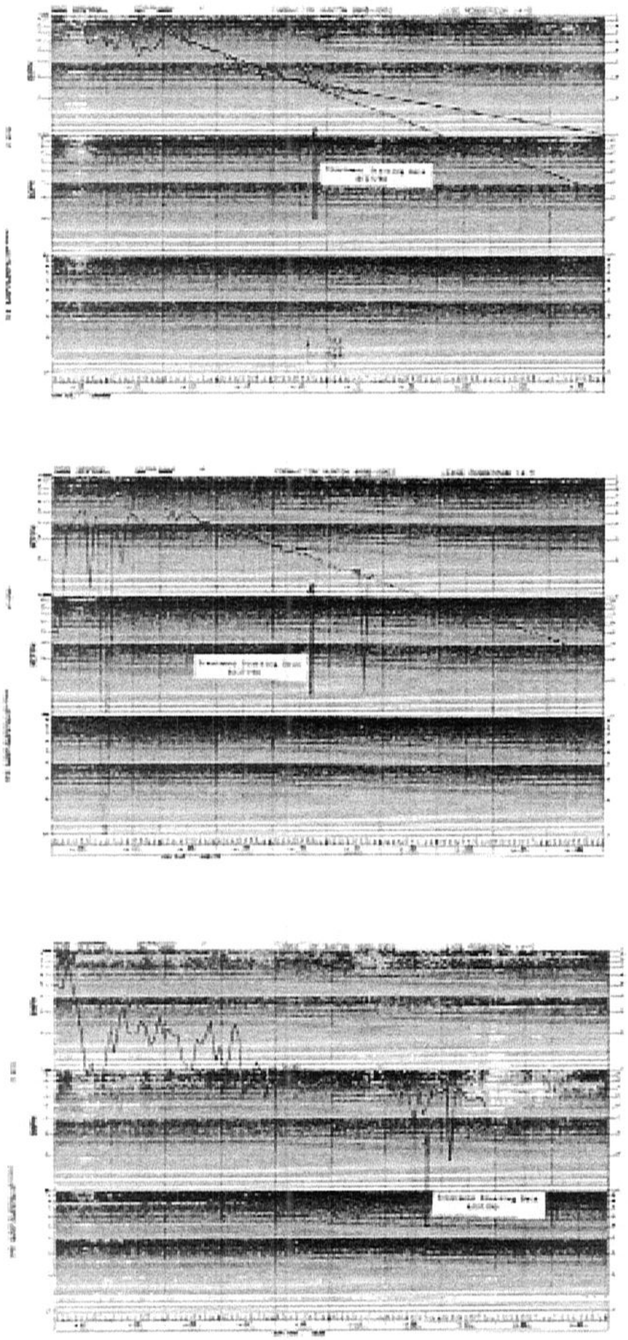

Fig. 1-J&P Robberson decline curves.

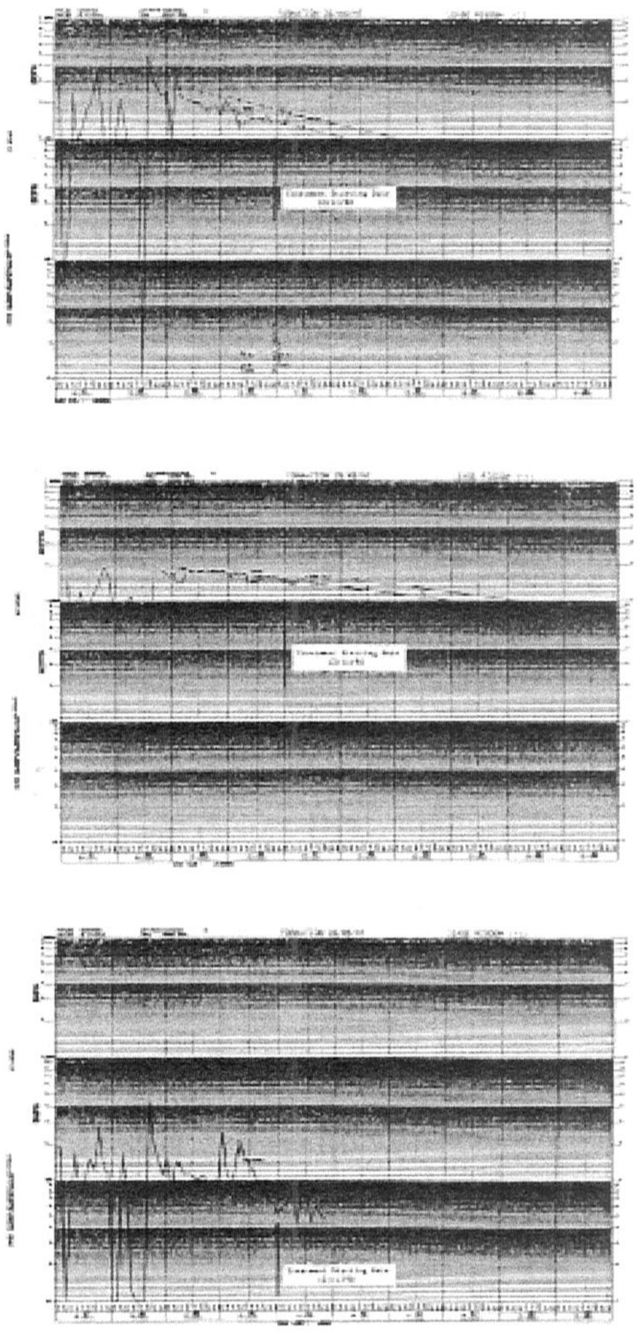

Fig. 2-FCD Rigdon decline curves.

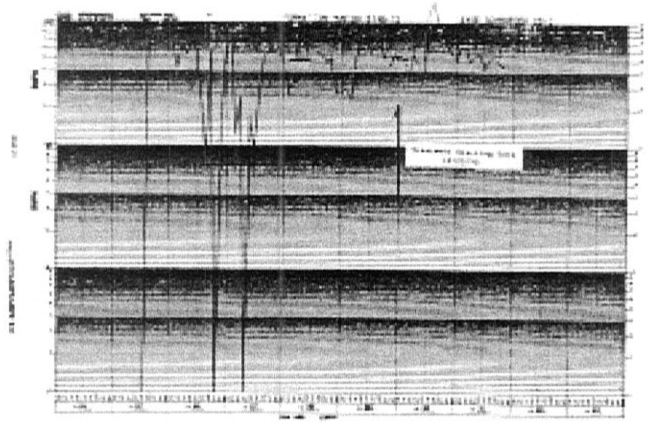

Fig. 3-J&P Schroeder decline curves.

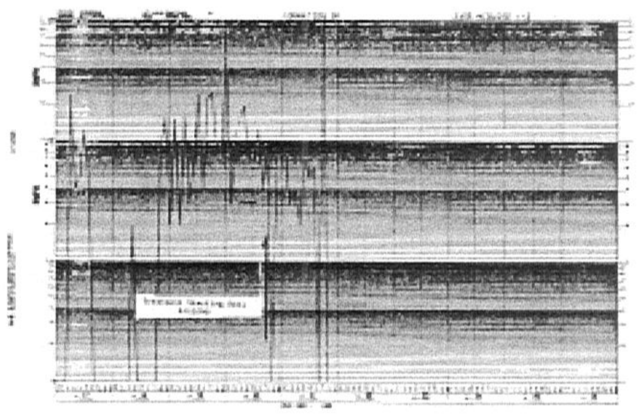

Fig. 4-FCD McGuire decline curves.