A New Solids-free Acid Diverting Agent – Case History

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Introduction

"Conventional acidizing has ignored relative permeability effects by attempting to inject aqueous fluids into zones filled with crude" [1,2] Since most oil wells in the Permian Basin today are on water flood or produce large quantities of water, relative permeability is an issue. Therefore in zones where the water saturation is high due to depletion of the higher permeability zones and/or natural fractures, acid tends to enter these zones instead of the oil zones where the acid is needed and wanted. This in turn leads to higher water cuts instead of increased oil cuts. A new non-particulate, non-gaseous material has been developed to effectively divert acid away from highly water saturated zones. This new material's diversion capabilities are dictated by the relative permeability of the formation as with foam, but it offers a simplicity and accuracy to the treatment that foam and other diverting agent can not. This paper discusses a case history that utilized this material for acid diversion in a water flood.

This field case study was implemented as a result of laboratory data that indicates that the new diverting material is substantially superior in oil stimulation than routine methods. The material is a visco-elastic surfactant that becomes viscous in the presence of brine. This solution temporarily blocks off the higher permeability streaks and/or the higher water saturated zones. This viscous fluid is polymer/solids free; therefore no damage occurs in the diverted permeability streaks. The fluid is designed to be field operational friendly. It can either be batch mixed or mixed "on the fly". This greater flexibility allows for adjustments to be made in the diversion stages on the fly. The ease and flexibility of field operations result in more efficient rig-ups and greater accuracy in placement.

The case study proves the capacity of the product and technique as a diverting agent based on treatment pressure data, both surface and bottomhole, and production data. An analysis of the production data is provided which compares the capabilities of the new solids-free acid diverting agent to standard treatments utilized in the same field on analogous wells. The material was tested under varied conditions and has proven to be highly effective in all areas.

Experimental Testing

The material and technique was first tested under laboratory conditions. The testing of the material is documented in SPE paper 39592.[2] The testing consisted of injecting fluids through Berea sandstone cores and measuring the amount of fluid that passed through each core (figure 1). This quantity of fluid was then converted to a fractional flow percentage. The data in figures 2-4 is presented in these fractional flow terms.

Flow tests were conducted under a variety of conditions to analyze the capabilities of the product. "These conditions include different water/oil saturation contrasts, treatment volumes, temperatures, multiple staged diverting agents, and damaged vs. undamaged cores."[2] Results prove that under laboratory conditions, the diverting agent was very capable of placing the stimulation fluid where needed. In every case, the flow pattern was altered. The stimulation fluid was diverted away from the water-bearing or undamaged core into the oil-bearing or damaged core. These results then led to the field case history.

Case History – Geology / Completion Technique

The field produces from the Grayburg Formation, a 250' sequence of interbedded dolomite and dolomitic sandstone deposited on a carbonate ramp setting along the northeast margin of the Delaware Basin during Permian (Guadalupian) time. The Grayburg is relatively thick and porous to the southwest (more packstones/grainstones) and thin and tight to the northeast (more wackestones/mudstones). These sets of parasequences stack to form six recognizable zones based on correlation's of relatively thin (approx. 2- to 10- ft thick), generally impermeable dolomitic sandstones (siliciclastics). Although there is a small amount of structural closure on the field, reserves in the field are primarily trapped stratigraphically by porous dolomitized grainstones and packstones pinching out updip (eastward) into tight dolomitized wackestones and mudstones. The best production occurs where the high wave energy shoal (grainstones and packstones) interfingers with the low wave energy back-shoal deposits (wackestones and mudstones). Outboard of this (westward) the more homogeneous, highly porous grainstones are lower on structure and tend to produce water encroaching from an aquifer to the west of the field. Inboard (eastward) of the interfingering area, the reservoir rock has reduced capacity due to the dominance of tighter dolomitized mudstones and wackestones that promote more of a solution gas-drive component.

Wells that are shown in this case history are all newly drill wells open hole completed in the Grayburg formation and have never been stimulated. The wells were drilled conventionally to the top of the Grayburg and to TD with air/foam. Some of the wells have been cored for permeability analysis. The permeabilities range from <0.1 md to > 2,000 md with a porosity range from 1% to 20% based on logs. The treatment volumes were then based on this data.

Case History – Stimulation Procedure

The stimulation procedure is based on the log and core data that was given. Treatment fluid volume was determined from the gross height and estimated net height. The gross height was the total openhole height and the estimated net height was the openhole height that was considered to be productive, the "pay zone". Treatment procedure was as follows:

1. Pickle tubing with 300 gals of iron control acid. If the well would not circulate, then swab back acid.
2. Run in the hole to TD with tubing to spot a proprietary solution (10-20 gal/ft) across the gross interval to be treated. Pull up the hole with the tubing and set the packer.
3. Start pumping a spacer (tubing volume) of 4% KCl in order to displace the proprietary solution out of the wellbore.

4. Start pumping a stage of diverting material. Total diverting volume ranged from 10 – 15 gal/ft of the gross height with the solution concentration ranging between 2 – 4% dropped in 3 – 4 stages.
5. Inject a stage of acid. The total acid volume pumped was 28 gal/ft of estimated net height again dropped in 3 – 4 stages.
6. Repeat stages 5 and 6 until acid volume has been pumped.
7. Flush

The procedure did vary in some instances. If the interval was too large to treat in a single stage, an openhole packer was set and two different stages were pumped. Some of the treatments utilized perforated tailpipe while others utilized a sonic impulse tool. The diverting material was put to the test in a variety of conditions.

Case History – Results

The effectiveness of the new diverting material was evaluated based on treating pressure data as well as production data. On most of the wells, bottomhole pressure data was measured in addition to the surface pressure data to show the diverter's effectiveness. Production results are the final indication of the success or failure of the treatments performed on the well.

Pressure data shown in figure 5 was the first well treated. The treatment fluid was 15% HCl acid with a non-emulsifier and a scale inhibitor. The diverting agent pumped was a 2% solution. This well was done in two stages with an openhole packer and tailpipe perforated with ¼" holes. The first stage pressure data is shown. There were two shutdowns due to communication around the openhole packer. The first two diverter stages show no pressure increases while the third through the fifth diverting stages show pressure increases of 300 psi, 250 psi and 200 psi, respectively. Each pressure being higher that the last showing continual diversion. Based on the weak pressure responses, the solution was increased to a 4% solution for the rest of the treatments.

Pressure data presented in figure 6 is from a well that was treated with a 4% solution through a sonic impulse tool. The first part of the data was not acquired due to computer problems, but there was bottomhole pressure data. This data shows good diverting responses to the new diverting material. The diverting pressure again continually increases throughout the treatment, yielding favorable acid coverage of the openhole.

The field test pressure data in figure 7 was also treated with a batch mixed 4% solution. The first part of the data shows the spotting of the proprietary solution, followed by pulling out of the hole with the tubing and setting the packer. The first stage of the diverting agent increased the bottomhole pressure by 500 psi and the second stage showed an increase of 550 psi. Again, pumping was shut down due to communication around an openhole packer. Once pumping resumed, the pressure never returned to the same level as before the shutdown. It was thought that there was continual leakage around the openhole packer.

The final pressure and rate plot, figure 8, was from a treatment where a 4% solution was mixed on the fly. This job was also pumped through a sonic impulse tool. The diverting material's viscosity was measured at the mixing tub to assure that the viscosity was developing. Viscosities were very close to that of the batch mixed fluid. Bottomhole pressure showed a continual increase throughout the treatment with little to no breaks. This signifies continual diversion and new formation being treated on every acid stage. Last, the surface treating pressure also demonstrated the frictional pressure reducing properties of the fluid. As the fluid passes through the sonic impulse tool, there was a pressure drop of 200-400 psi noticed.

The above data proved that the material is an excellent diverting agent, but production data must support the treatment data in order to determine the overall success of the treatment. Therefore production data, figures 9-21, was collected to demonstrate the overall capabilities of the new diverting material. Results from treatments that used other diverting agents in wells of similar characteristics are included for comparison. These other diversion methods and treatment types include:

1. Nitrified foam as a diverting agent
2. Xylene emulsion as a self-diverting acid.
3. Acid wash with no diversion.

The size of the diverting stages and acid volumes varied from well to well, but the overall production results are summarized in table.

Conclusions

1. The product is a new viscous diverting agent that is non-gaseous and requires no solids for diversion.
2. It is cleaner than traditional diverting agents because it is polymer free.
3. The new diverting agent is safer and easier to execute than those utilizing energized fluids.
4. Treating pressures and production results prove that the diverting agent is significantly more effective than other diverters that were tried on the newly drill wells.

References

1. Gildy, J.L.: "The future of Acidizing," JPT March 1997, 230.
2. Chang, F.F., Thomas, R.L., and Fu, D.K.: "A New Material and Novel Technique for Matrix Stimulation in High-Water-Cut Oil," paper SPE 39592 presented at the 1998 SPE International Symposium on Formation Damage Control held in Lafayette, LA, February 18-19, 1998.

Table 1 - Summary of Production Results for Different Treatments

Material	New Diverting Agent – Before (6)	New Diverting Agent – After	Acid Wash – Before (2)	Acid Wash – After	Foam – Before (3)	Foam – After	Xylene Emulsion – Before (3)	Xylene Emulsion -After
BOPD	37.2	73.2	24.5	52.5	1	3.5	19.3	28.3
BWPD	483	1397	215	270	251	255	60	150
MCFD	15.8	39.7	7	19.9	1.0	1.0	1.7	7.3
Oil Cut	7.0	5.0	10.0	16.0	0.4	1.4	24.3	15.9
3 month Decline		6.8		12.0		5.0		19.0

* The three month decline was estimated on some of the wells that have not been on production this long after treatment.

This table shows the average production from the treated wells and the average decline after three months of production. The number after the treatment shows the number of wells treated with that method. As indicated previously, these wells are in a water flood, so an increase in total fluid production is a goal in most cases for a stimulation treatment. With this in mind, the new diverting agent has a total fluid production increase of 282%, with gas production increasing by 251%. This clearly proves that the new diverting agent is an effective diverter.

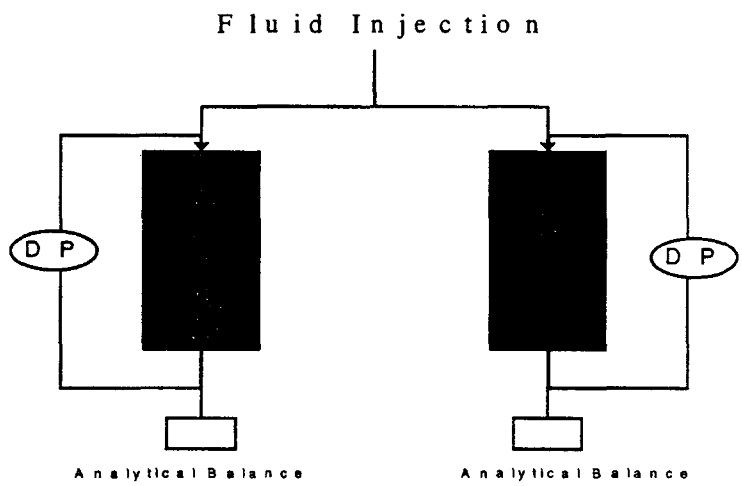

Figure 1 - Laboratory Setup for Testing of the Diverting Agent [2]

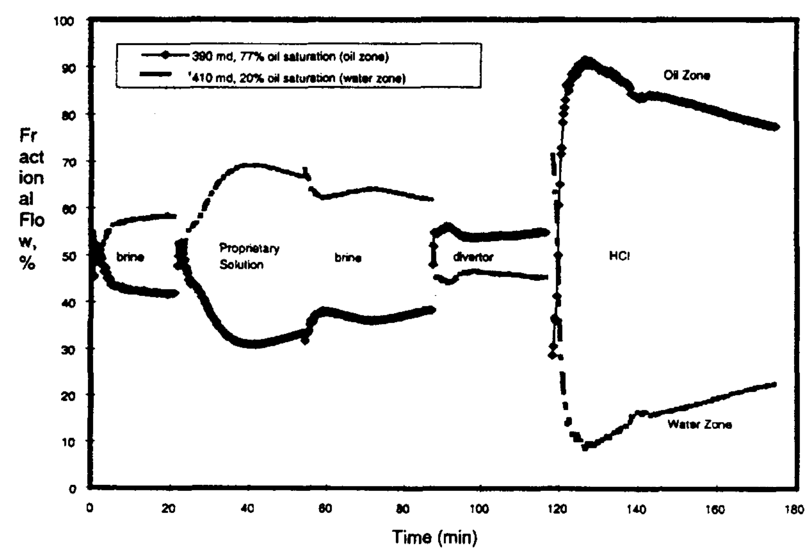

Figure 2 - Plot of Data from SPE 39592 Showing Fractional Flow Behavior of the Stimulation Technique [2]

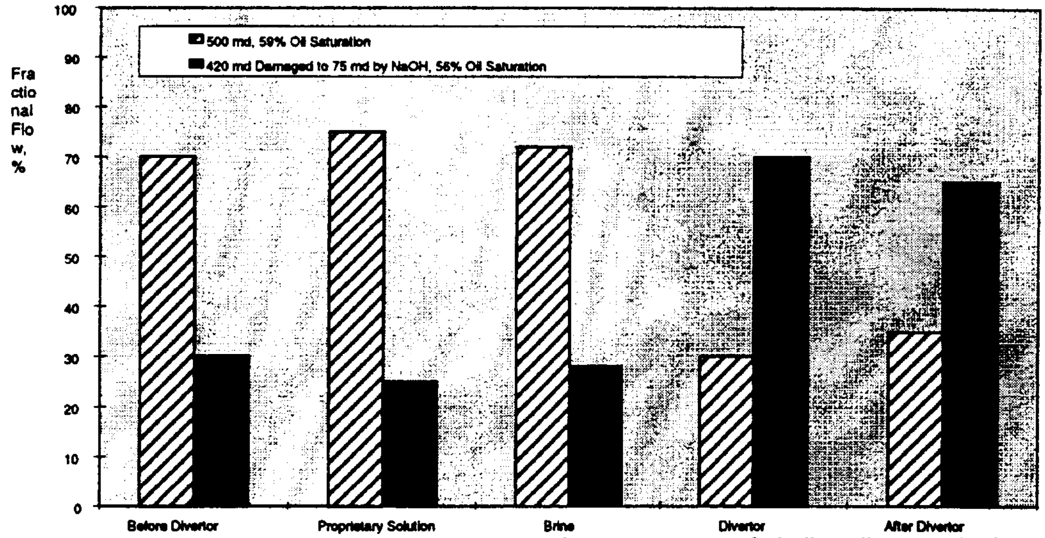

Figure 3 - Plot shows how the technique performs on cores of similar oil saturation's, but different permeabilities.[2]

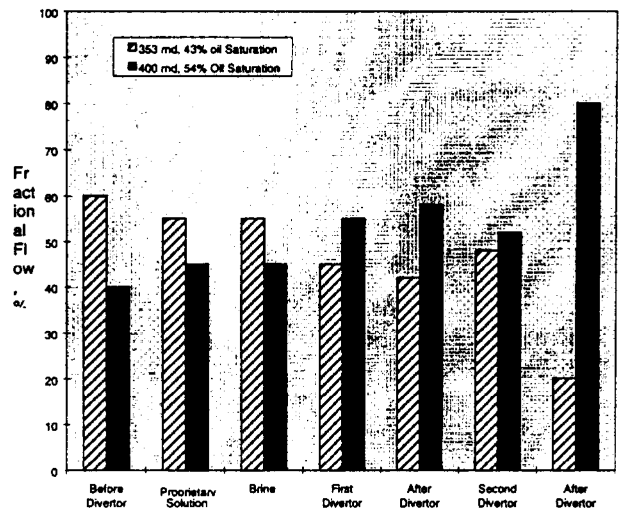

Figure 4 - This plot demonstrates the complete technique that is used in the case study. The diverting agent once at the interface begins to change the flow regime and allows for the acid to be diverted to the necessary core. [2]

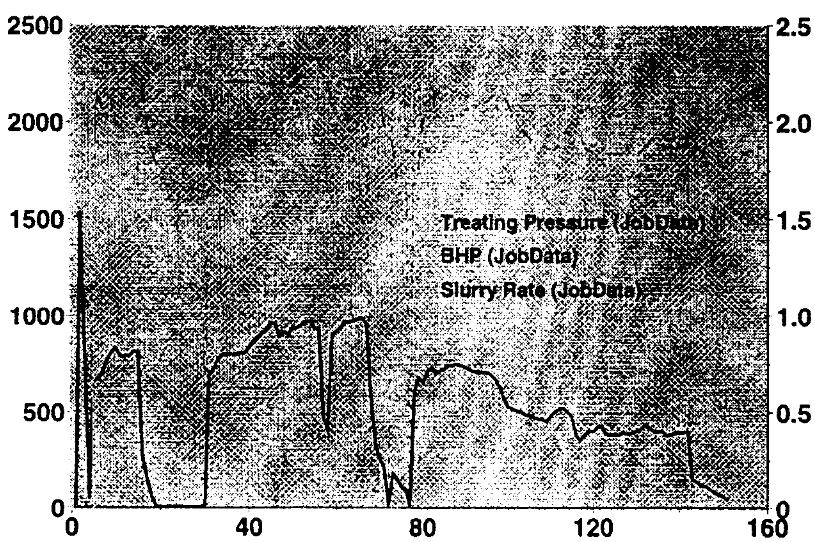

Figure 5 - Treatment Data from the First Well Treated with the New Material This is a batch mixed 2% solution.

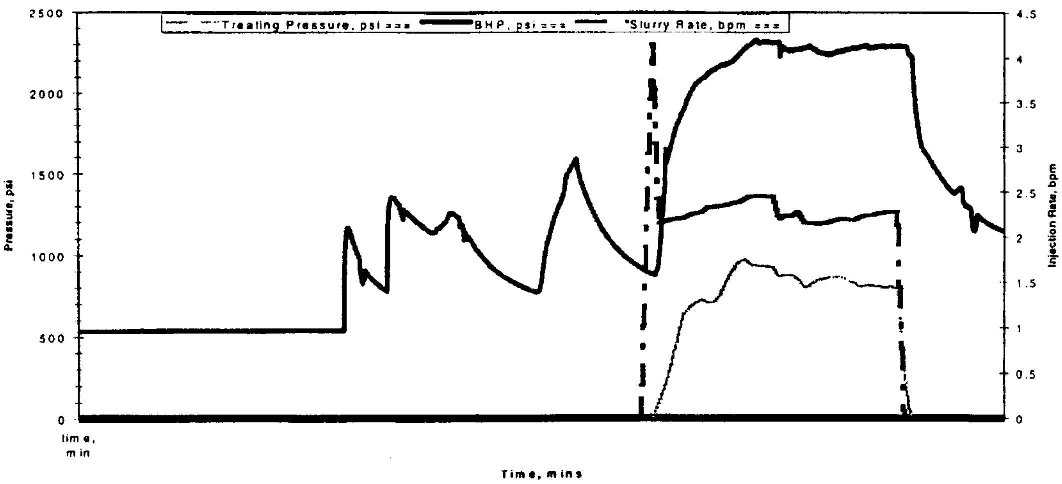

Figure 6 - Treatment Data from a 4% Solution Treated Well
There is a loss of surface data due to computer problems. The diverting agent demonstrates its capabilities based off of the bottomhole pressure data.

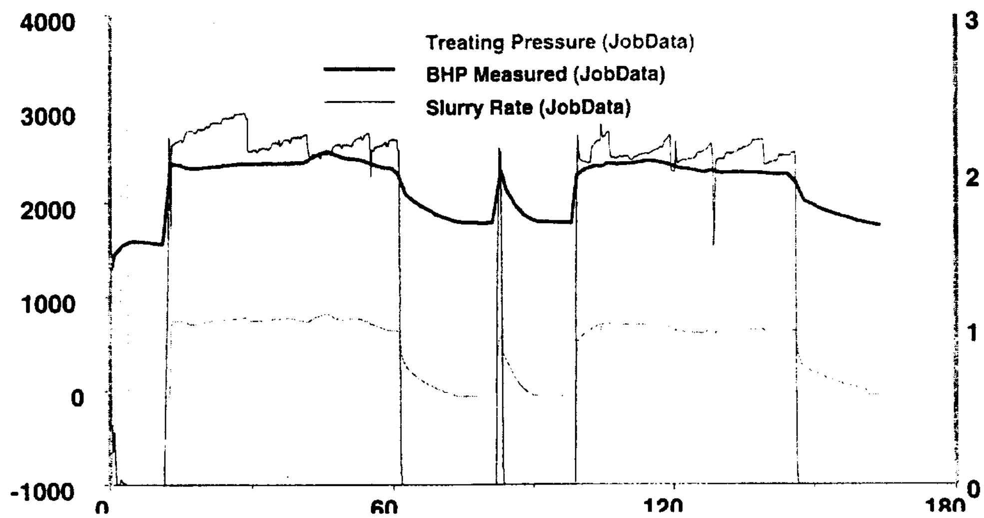

Figure 7 - This pressure data shows 4% diverting solution. There are two shutdowns during the job due to communication around an openhole packer.

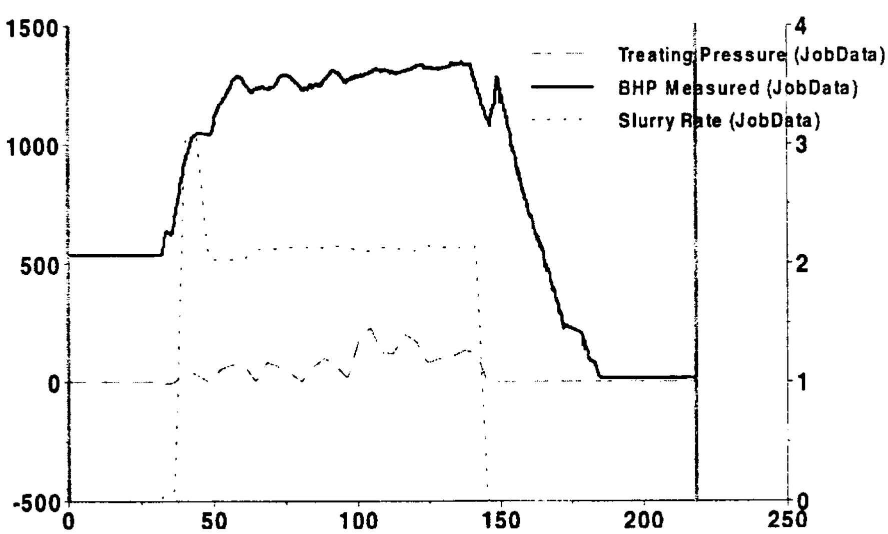

Figure 8 - The new diverting material was mixed "on the fly" during this job Continual bottomhole pressure increases lead to better coverage of the acid.

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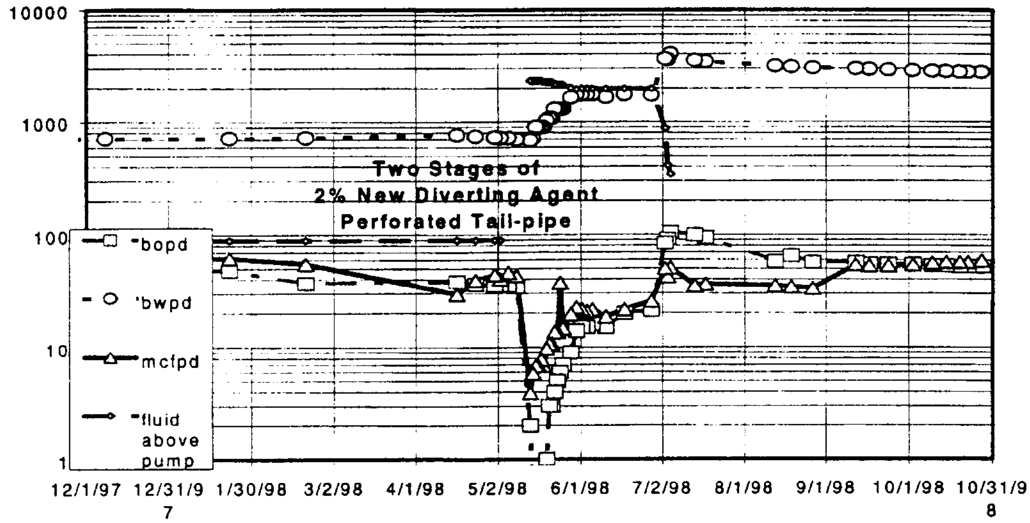

Figure 9 - Production History from the First Well Treated with the New Diverting Agent

584

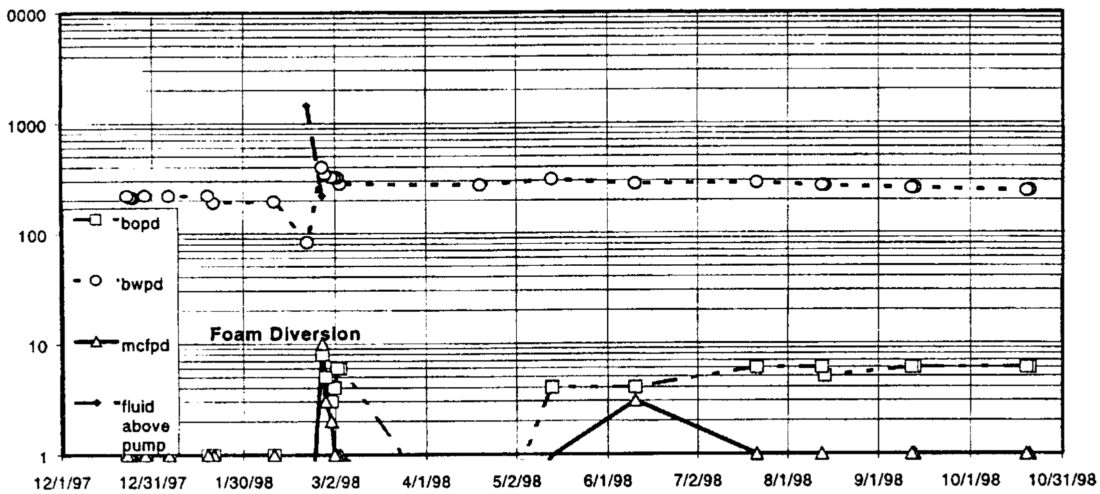

Figure 10 - Production Data from One of the Foam Diversion Jobs
There is minimal production increase.

699

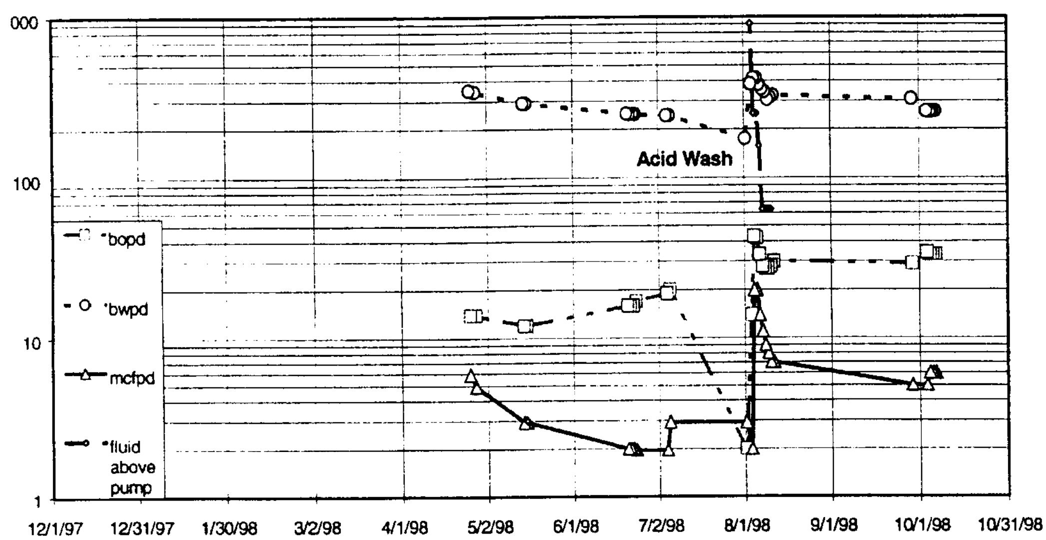

Figure 11 - This graph shows the production data from an acid wash.
No diversion was performed on this well.

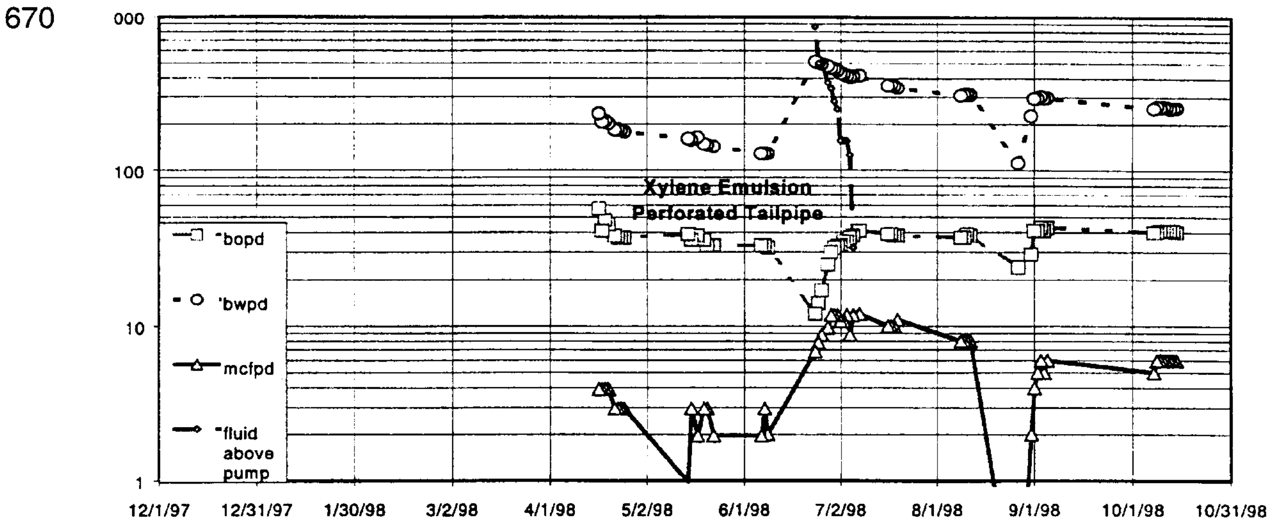

Figure 12 - Production Plot from a Self-Diverting Xylene Emulsion Treatment

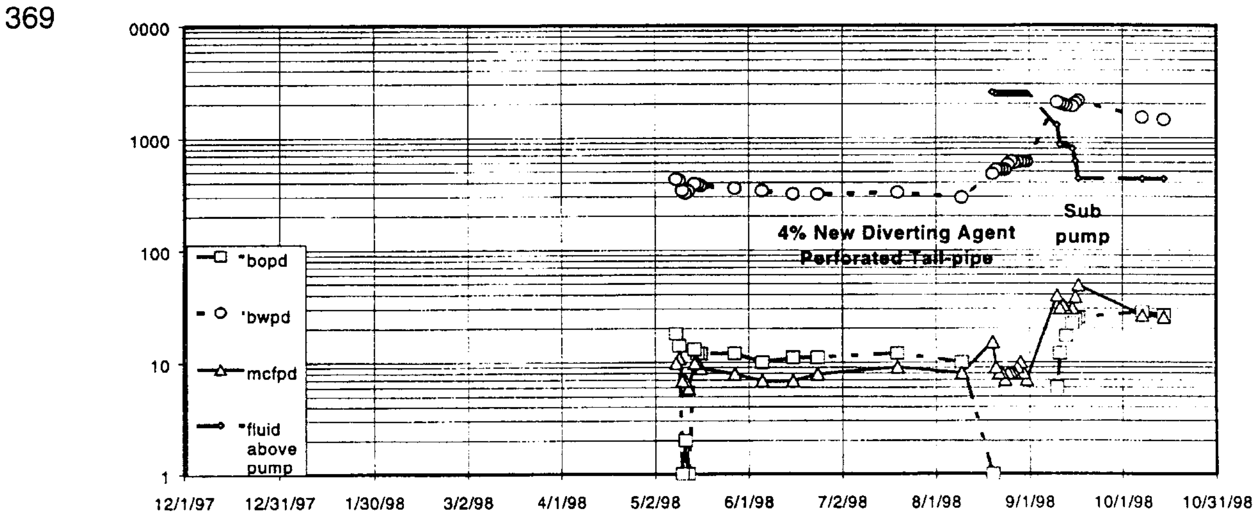

Figure 13 - Production from a 4% New Diverting Agent Treatment through Perforated Tailpipe

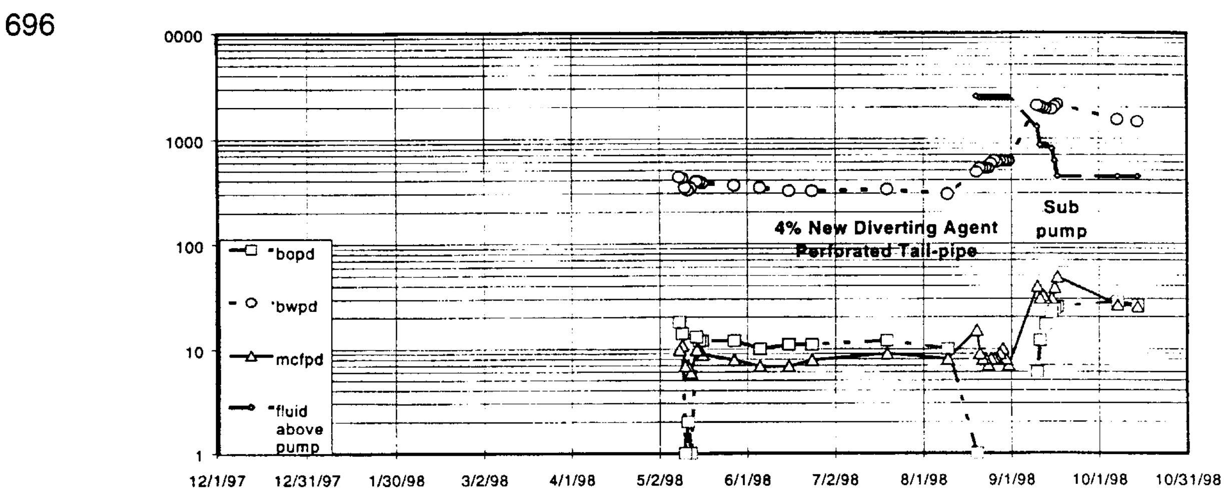

Figure 14 - A Well That Was Initially Treated with Foam Diversion
The well had a bad emulsion problem from the foaming surfactant, so it was re-stimulated with the new diverting agent to try to clean up the emulsion.

640

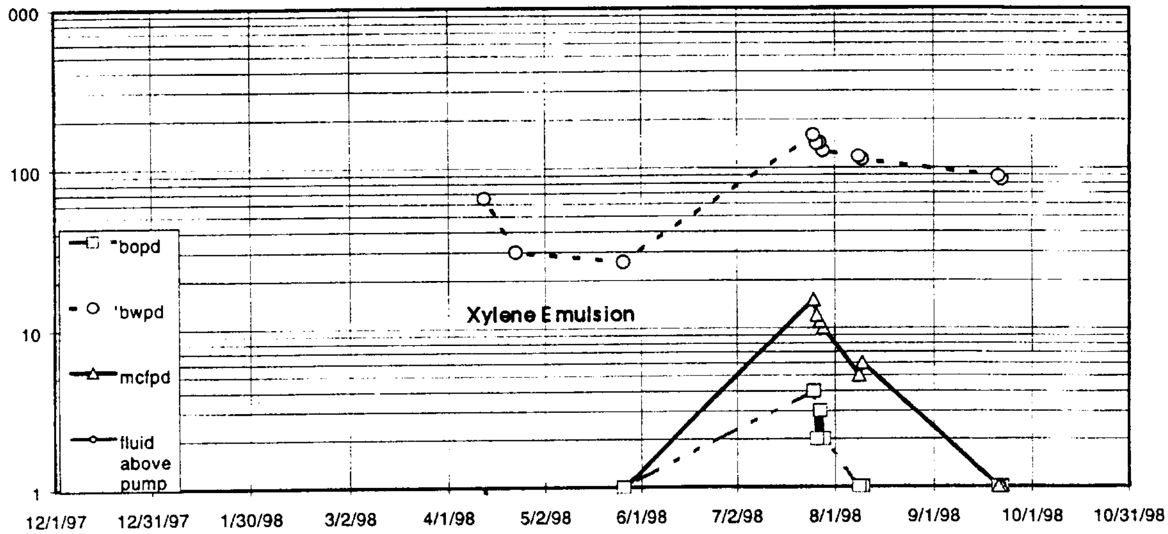

Figure 15 - Xylene Emulsion Treatment that Showed a Temporary Increase in Production, but Fell Off After Two Months

653

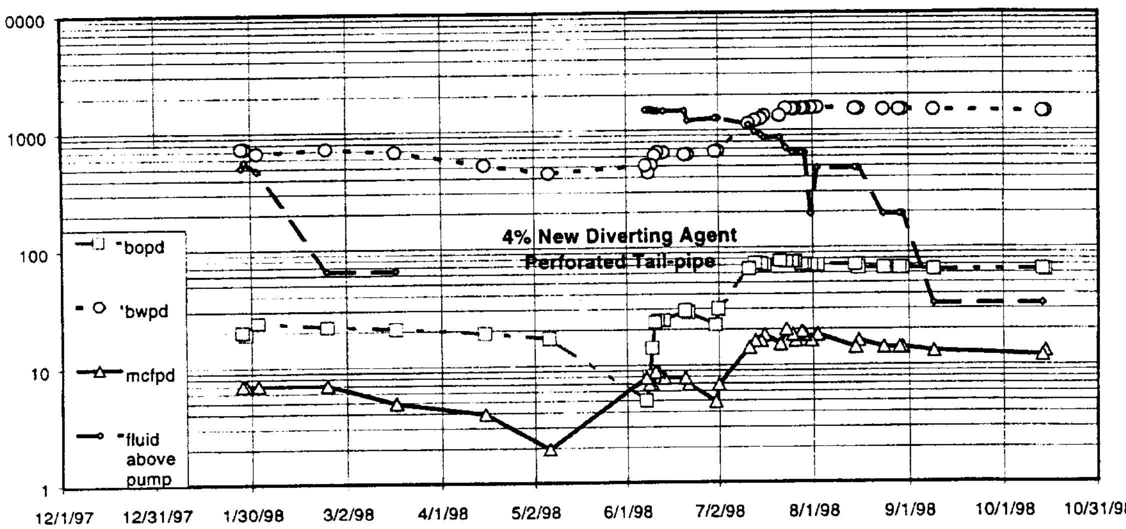

Figure 16 - New Diverting Agent Production Data from a 4% Solution Treatment

669

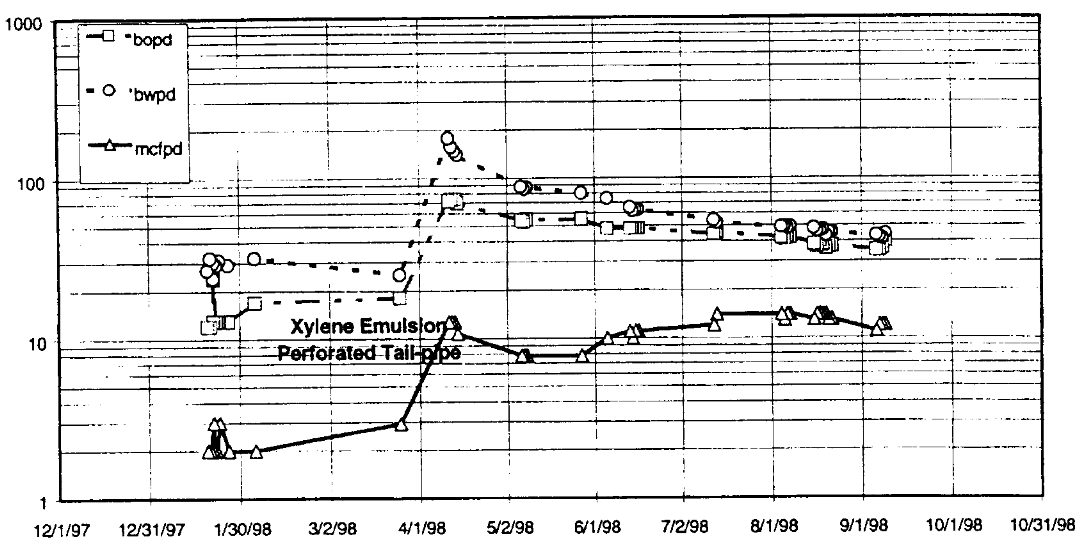

Figure 17 - Best Production Results for the Xylene Emulsion Treatment

390

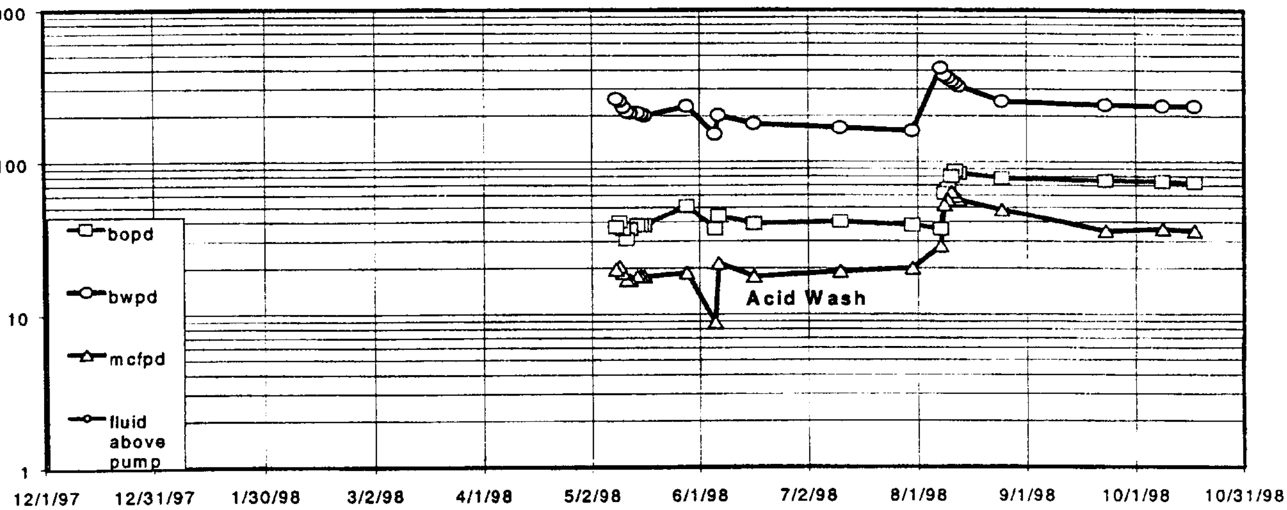

Figure 18 - This plot shows the best production results from an acid wash with no diversion.

359

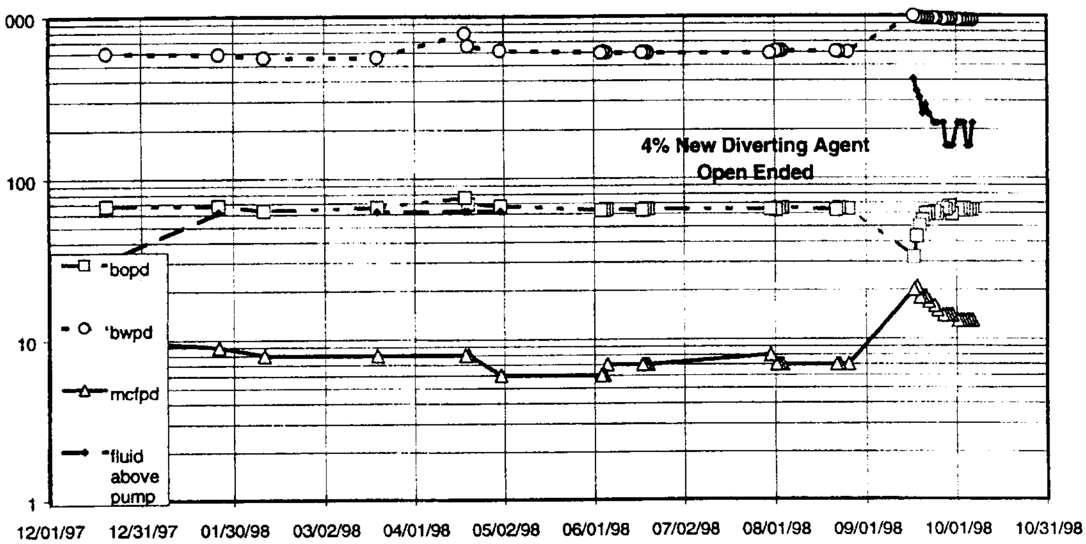

Figure 19 - 4% Solution Pumped through Open Ended Tubing

347

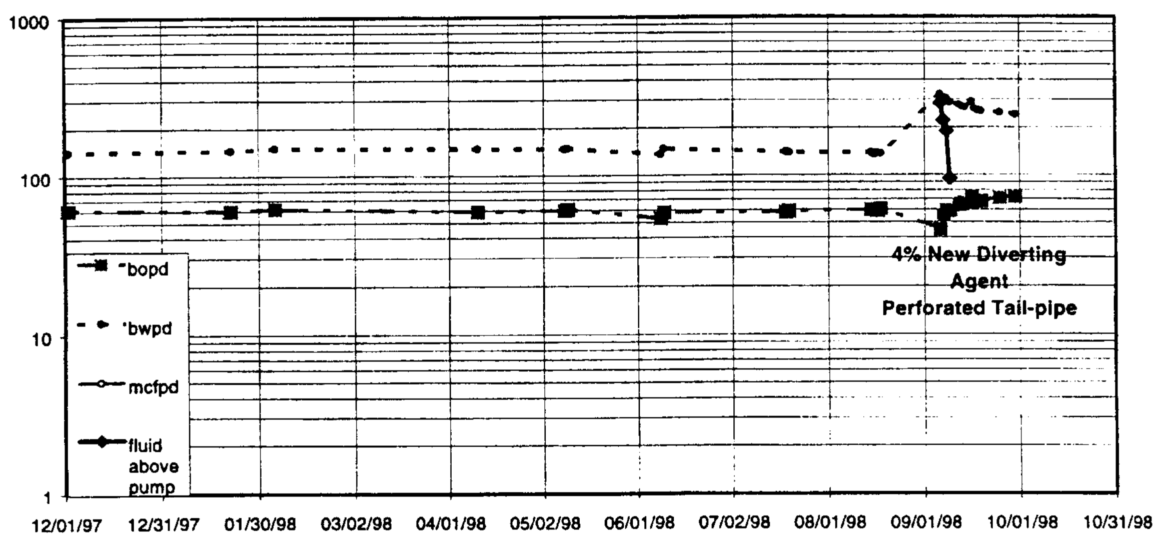

Figure 20 - This is the production for the well that was treated with the new diverting material mixed "on the fly."

652

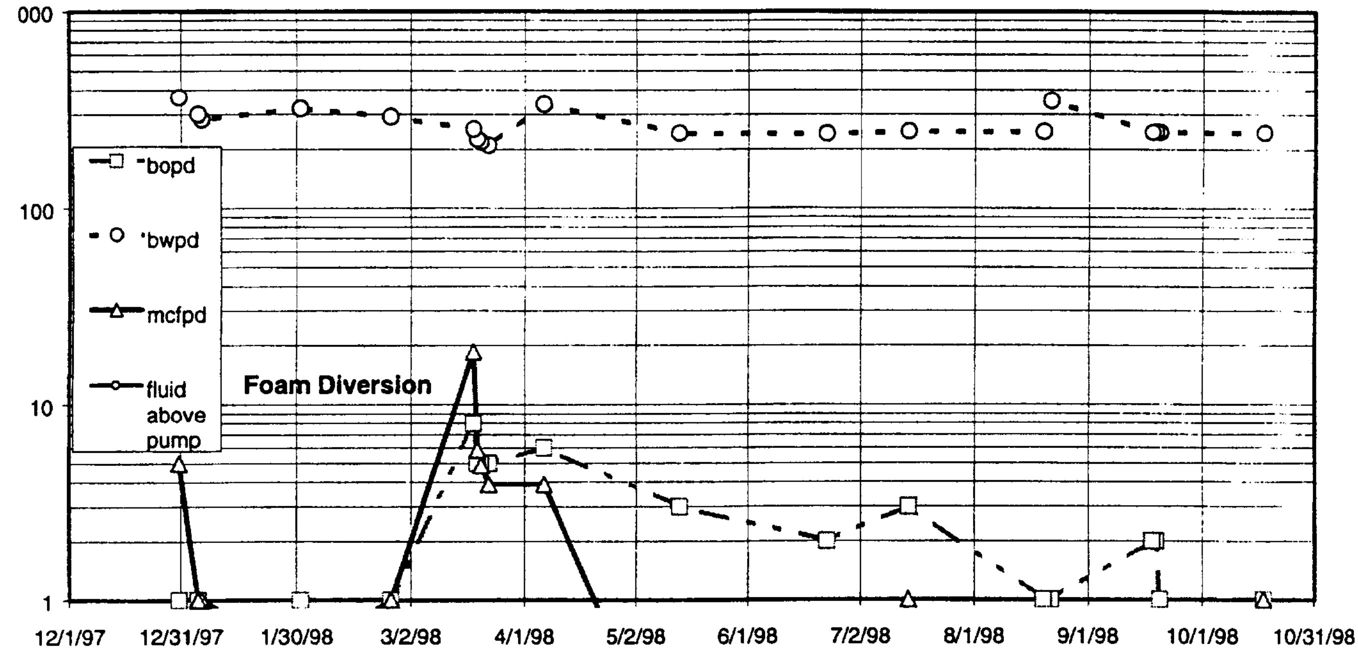

Figure 21 - Production Data from a Foam Diversion Treatment
This well again had bad emulsion problems due to incompatibility
with the foaming surfactant.

336

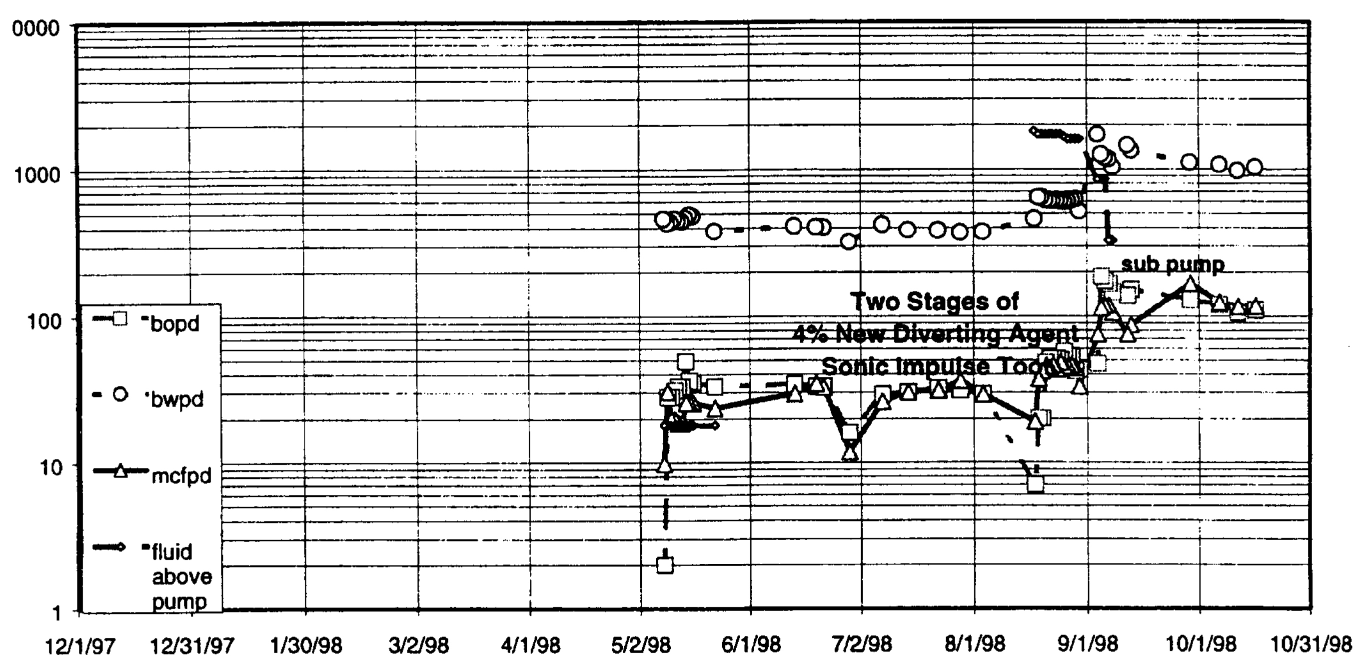

Figure 22 - This is the best producing well out of the newly drilled wells. It was treated in two stages with a 4% solution of the new diverting agent.