PROPPANT FLOWBACK CONTROL USING COST EFFECTIVE METHODS

D. Paul Sparks, Amoco Production Co.*
Jim Kirksey, Dowell Schlumberger, Inc.
John G. Hoffman, Amoco Production Co.
John Carlton, Dowell Schlumberger, Inc.

During the past several years, production and service companies have been trying to solve an old problem that occurs after fracture of productive zones in the Permian Basin. Many solutions have been used with little or no success to prevent proppant flowback. The problem of proppant flowback occurs in both cased hole as well as open hole completions.

New applications using old completion technology have been applied recently to improve control of proppant flowback. The technology used was developed from sand control methods dating back to the 1970's.[1,2,3,4] These methods consist of slurrying the same mesh sand used during the fracturing process with a resin. This yields a complete sand resin and catalyst mixture to ensure proper setting of sand. The ability to alter the catalyst makes it an attractive alternative due to the wide range of pump times available. The original slurry was developed to place an artificial zone in a hard rock, open hole environment following a propped fracture treatment. The slurry is allowed to set up and then drilled to a size known to be smaller than the original open hole section. This will give a permeable ring of resin-set sand to prevent proppant from flowing back into the wellbore.

The liquid resin squeeze technique, used in a cased hole application, was conceptually designed to utilize the in-place proppant material. This resin bonding of the proppant will create a permeable barrier preventing proppant flow into the wellbore.

This paper will describe, in detail, a case study of a field in West Texas and how to prevent proppant flowback in both open and cased holes using slurried resin and sand. It will also evaluate the well's performance.

Field Description

The North Cowden Unit is a secondary and tertiary recovery project which is operated by Amoco Production Company. The Unit lies on the margin of the Central Basin Platform and the Midland Basin in Andrews and Ector Counties, Texas. The Unit comprises over one-half of the North Cowden Field, which spans roughly 200 square miles.

* Currently employed with Taurus Exploration, Inc.

The North Cowden Field was discovered in 1930 and produced under solution gas drive until 1950, when a cooperative gas injection project was initiated. The Unit was formed in 1966 and water injection commenced in 1967.

The North Cowden Unit produces from the Grayburg formation which is of Permian age. The Grayburg formation is highly stratified and is comprised predominantly of dolomite with varying percentages of sand and anhydrite. The top of the Grayburg is at an average depth of 4,100 feet. The formation has a gross pay thickness of approximately 500 feet, of which, approximately 200 feet is productive. The Grayburg horizon is an anticlinal structure with the oil accumulation associated with a combination structural, stratigraphic trap.[5]

Introduction

Hydraulic fracturing has been used successfully and frequently since its introduction to the industry in 1947 in the Hugoton Field.[6] As field results and many previous authors have shown, hydraulic fracturing in low to moderate permeability reservoirs can accelerate recovery. Without this process, some wells would not produce at an economic level. As stimulation technology has advanced, the ability to place larger diameter proppant at higher concentrations into induced reservoir fractures is more commonplace. These higher concentrations of proppants coupled with the practice of under-flushing leaves a large volume of proppant near the wellbore. This wellbore area can be quite large in the case of a "shot" (nitroglycerin stimulation) open hole, which was common practice in the 1930's, or after repeated acid treatments in an open hole carbonate formation. Likewise in wells completed with perforated casing, proppant flowback can present as serious a problem as an open-hole completion.

Proppant flowback after fracturing has long been an operational problem in artificially produced wells.[7] The produced proppant has caused mechanical failure with the artificial lift methods generally used (electric submersible pump, beam pumps, etc). To facilitate the use of fracturing and still maintain minimal operational expense, a process was needed to prevent post-fracture proppant flowback in wells. Many techniques to reduce pump failures have been tried by operators, including overflushing the proppant (which is detrimental to near wellbore conductivity), continuous use of resin-coated sand throughout the job (expensive for low closure stress requirements), and raising the pump above all zones that were stimulated (does not allow full well drawdown due to fluid head above the productive interval). As can be seen, the previous solutions were not economically favorable for producing characteristics. Even after fracture treatment "clean outs" with various systems and procedures, produced proppant has continued to cause excessive pump failures.

Produced proppant causes abrasion and/or failure. This situation creates two economically detrimental problems: 1) deferred production revenue due to well downtime, and 2) expense of repairing the well to an operational mode. This paper presents two methods of helping to alleviate sand production from both cased hole and open hole completions.

Solution

In the North Cowden Unit, a major component of most well completions is propped hydraulic fracturing. The majority of most recent hydraulic stimulations in the field were performed with a borate salt crosslinked polymer system carrying sand concentrations in excess of eight pounds of 12/20 proppant added to one gallon of fluid, pumped at rates greater than 40 barrels per minute. These jobs were economic successes and were an attractive opportunity for continued work in old and new producing wells. One notable problem in post-fracture producing wells was proppant production. This trend was observed in approximately 10% of all wells hydraulically fractured. Of these "problem" wells, pump failures were averaging up to one failure per week. To alleviate this problem and decrease field operating expense, alternate fracturing techniques were designed and implemented.

The original modification to the fracturing program was to "tail-in" (last portion of proppant slurry pumped) with resin-coated sand. This procedure produced mixed results. While being successful on some wells, it proved unsuccessful in others. It was perceived that with the large gross interval, some sections may have screened out prior to the end of the treatment and the resin-coated proppant was not being adequately placed throughout the zone. The use of resin coated sands also added significant costs to the fracture treatment and with only about 10% of the wells becoming problem wells, it was felt that a remedial process used on an "as needed" basis would be a better approach.

The first technique designed was for an open hole completion and called for the use of a water-based resin system carrying 20/40 mesh sand. This water-based resin system consists of three parts: the carrying fluid (in the case of Cmhec thickened brine), the proppant, and the epoxy resin system. The resin system consists of the resin solution, an amine-curing agent solution and an aminosilane coupling agent.[8,9]

The slurry was placed across the producing interval, completely filling the open hole section (Figure 1). Surface pressure was applied to squeeze the slurry into the near wellbore region of the fracture. The mixture was allowed to set and was then drilled out with a bit size smaller than open hole section. This allowed a highly permeable ring to be left around the wellbore allowing well fluids to be produced, but trapped any proppant that tried to migrate into the wellbore. Conventional northern white frac sand used in the resin system yields high permeabilities with good grain to grain resin bonding (Figure 2). Measured permeabilities in the range of 150 to 220 darcies are reported (Table 1). A generalized procedure is as follows:

1. Rig up service unit.

2. Tag total depth for fill with production equipment.

3. Run caliper log to determine hole size. This will be used to calculate volumes of resin slurry to be pumped.

4. Trip in hole with packer and open hole length of tailpipe. The tailpipe should be fiberglass for easy drill-up should tubing become stuck.

5. Land tubing so that tailpipe is 10' off bottom.

6. Load hole with fresh water.

7. Pickle tubing with 15% HCL followed by fresh water to displace acid.

8. Pump fresh water followed by spotting across the open hole interval the calculated volume of water-based resin slurry. The volume is calculated by calculating the open hole volume and the volume of the created hydraulic fracture up to one foot from the wellbore.

9. Pull up and set the packer above open hole where tailpipe is clear. Set packer and attempt to load hole with fresh water.

10. Leave well shut in for at least 24 hours.

11. Drill out to TD with drill bit that is smaller than original open hole size.

12. Return to production.

Cased hole applications presented a much more serious problem. Since the casing acts as the protective sheath, the perforations are now the entry point into the wellbore through which the proppant travels. A sand laden slurry would be difficult to place at matrix injection rates and placement could not be guaranteed throughout the fracture.

Removing the sand from the slurry would overcome this problem, but other placement problems had to be solved. The most important of these were uniform placement throughout the fracture face and how to enhance the environment so that the resin would be attracted to the grains in the existing prop pack.

A placement technique was developed that would attempt to solve both problems. First, a packer and tailpipe would be used to ensure that all fluids could be spotted across all perforations. Secondly, a sequence of fluids was then developed that would first be spotted across all perforations and then slowly pumped into the fracture to clean the sand and leave the sand pack clean and water wet. It is important that the sand be strongly water wet to attract the resin. The resin would also be underdisplaced to prevent overflushing. The amount of resin to use was calculated by calculating the cased hole volume, tubing volume required, and resin to fill three feet into the fracture over the expected gross fracture height. It was felt that if the sand pack could be partially coated up to three feet that adequate bonding would develop to prevent proppant migration (Figure 3). A procedure for this is as follows:

1. Clean out well to TD.

2. Trip inhole with packer and tailpipe.

3. Pump +/- 24 barrells of fresh water, leaving the packer unset.

4. Pickle tubing with 15% HCL with corrosion inhibitor and cationic wetting agent. (This will leave the proppant pack water wet, thereby attracting the resin to the proppant). Close in the backside with 2-3 barrells acid remaining and after all acid is pumped, set packer.

5. Pump two tubing volumes of fresh water behind acid after packer is set with one gpt cationic wetting agent.

6. Pump calculated volume of resin.

7. Pump half a tubing volume of fresh water.

8. Let stand for 30 minutes, then pump remaining tubing volume of fresh water.

9. Let well become static, release packer and trip out of well.

10. Shut well in for 24 hours.

11. Clean out well and return well to production.

Attention must also be focused on good completion pratices, such as sparse use of pipe dope on pin ends only, and tubulars should be pickled and all brines filtered. The more attention paid to the quality control process--the better the result should be.

Field Mixing

The simplicity in mixing requirements contribute greatly to the success of these slurries. The aqueous based system is commonly used along the Gulf Coast for sand control. This means a set of established mixing and quality control procedure were available. The most important of these is that the base water be filtered free of solids, the mixing equipment be dedicated to resin service, and that the sand used be the highest quality available. The mixing of the resin system itself is quite simple. The base water is thickened. A chelant is then added to complex any multivalent cations present in the water (Ca^{++}, M_g^{++}, F_e^{++}, etc.) followed by an cationic wetting agent to water wet the sand. The carrying fluid is then tested for viscosity and for unchelated multivalent ions. The sand is then added and blended. To this slurry, the resin is then added along with the coupling agent and a hardening agent. Finally an accelerent, if needed, is added and blended for 15 minutes. Five minutes prior to pumping, a gell breaker can be added if needed. The slurry is then ready to pump. Equipment requirements for this service were standard gravel packing, blending, and pumping eqipment.

CASE HISTORIES

Open-Hole Completion

A hydraulic fracture stimulation was performed on North Cowden Unit #824 in January of 1988. The stimulation consisted of pumping 50 thousand gallons of Borate crosslinked polymer with 160,000 pounds of 12/20 proppant at high rates. Flush volumes for the job were calculated to within 100' of the casing shoe. The wellbore was cleaned out to total depth and the pump was installed. After production equipment installation, pump failures attributable to proppant were occurring at the rate of one per week while increasing operating cost and well downtime. It was decided to try and use the open hole procedure listed previously to alleviate the proppant flowback problem. As can be seen (Figure 4), the pre-stimulation production was 28 BOPD and 220 BWPD with continued well problems not allowing an initial post-fracture rate to be established. Immediately following the resin-sand slurry treatment (February 1988), the well was tested for 30 BOPD x 300 BWPD while pump failures related to sand production were not noted. The most important aspect of this method was that the well could be pumped for a long enough period to decrease the fluid level. The decreased wellbore hydrostatic allowed the well to produce 60 BOPD x 220 BWPD (five months after treatment).

Cased Hole Completions

Prior to the proposed fracture treatment (same fracture treatment design as the open hole well), the well was producing 12 BOPD and 26 BWPD. Post-fracture production was 60 BOPD and 180 BWPD with repeated well downtime due to proppant production (Figure 5). The cased hole procedure mentioned previously was used to alleviate the produced proppant problem. Following the resin treatment, production was 52 BOPD and 130 BWPD with no downtime due to proppant production. This technique requires no drill-out operation or additional sand to purchase, thus offering an inexpensive approach in a cased hole environment.

Conclusions

1. This case study shows that the use of water-based resin systems is a cost effective method of controlling proppant flowback in wells with low closure stresses.

2. This system can be used as either a sand slurry for open hole completions or as a resin squeeze for cased hole applications.

3. The treatments require careful placement techniques to ensure zonal coverage and good quality control procedures to be successful.

Acknowlegement

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Table 1
Resin Slurry
Permeability and Compressive Strength

SAND SIZE	K (DARCIES)	COMPRESSIVE STRENGTH (PSI)
100 Mesh	26.9	4000 - 5000
20 - 40	91.0	2500 - 4500
12 - 20	255.5	2500 - 4500
8 - 16	296.2	

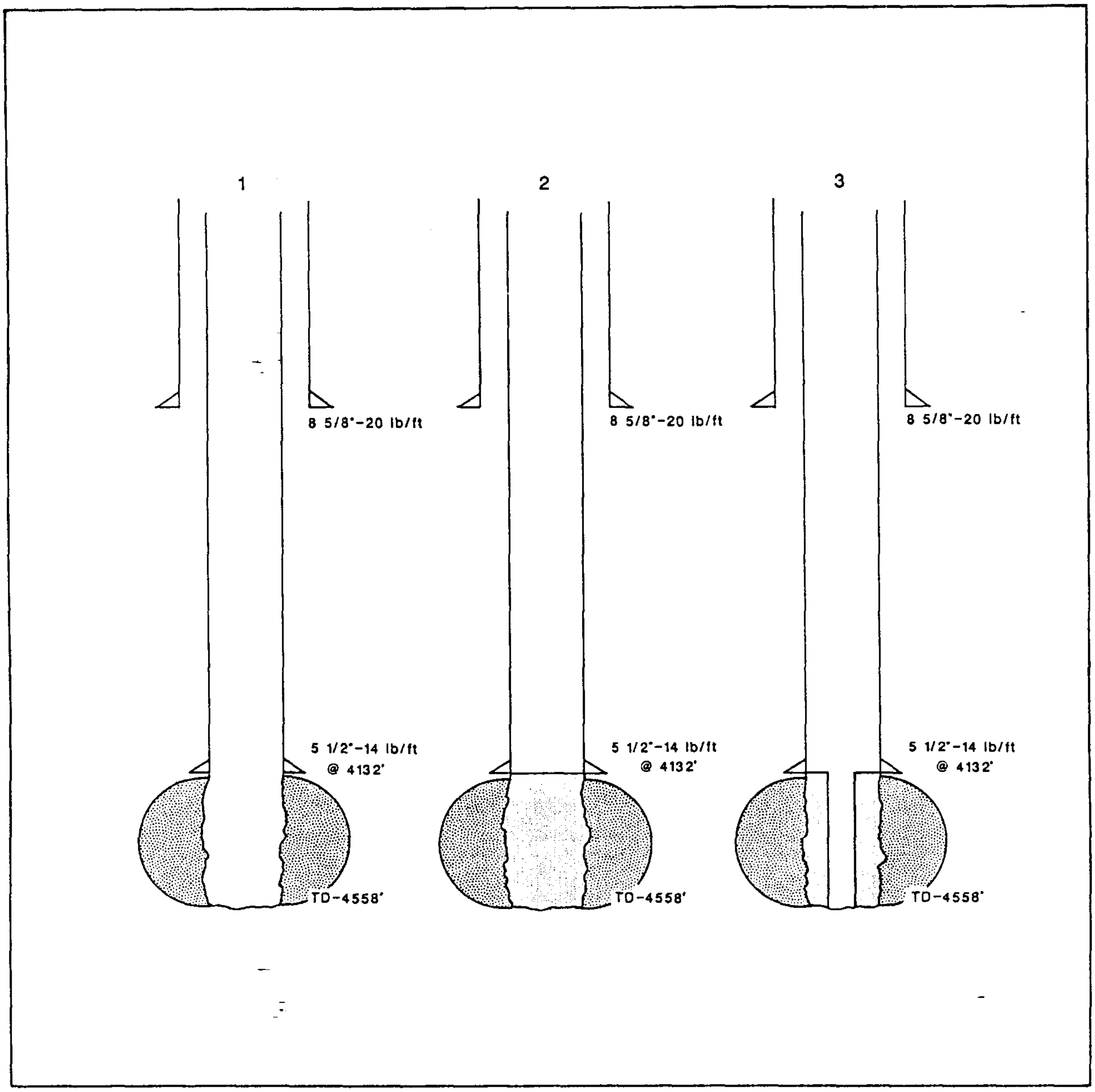

Figure 1 - Open hole technique

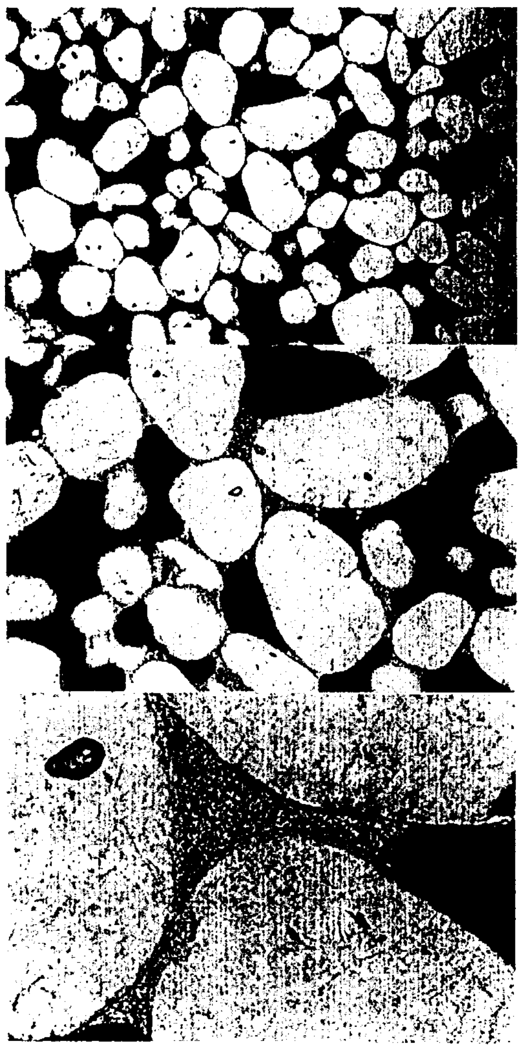

Figure 2 - Resin/sand bonding
(three increasing magnifications)

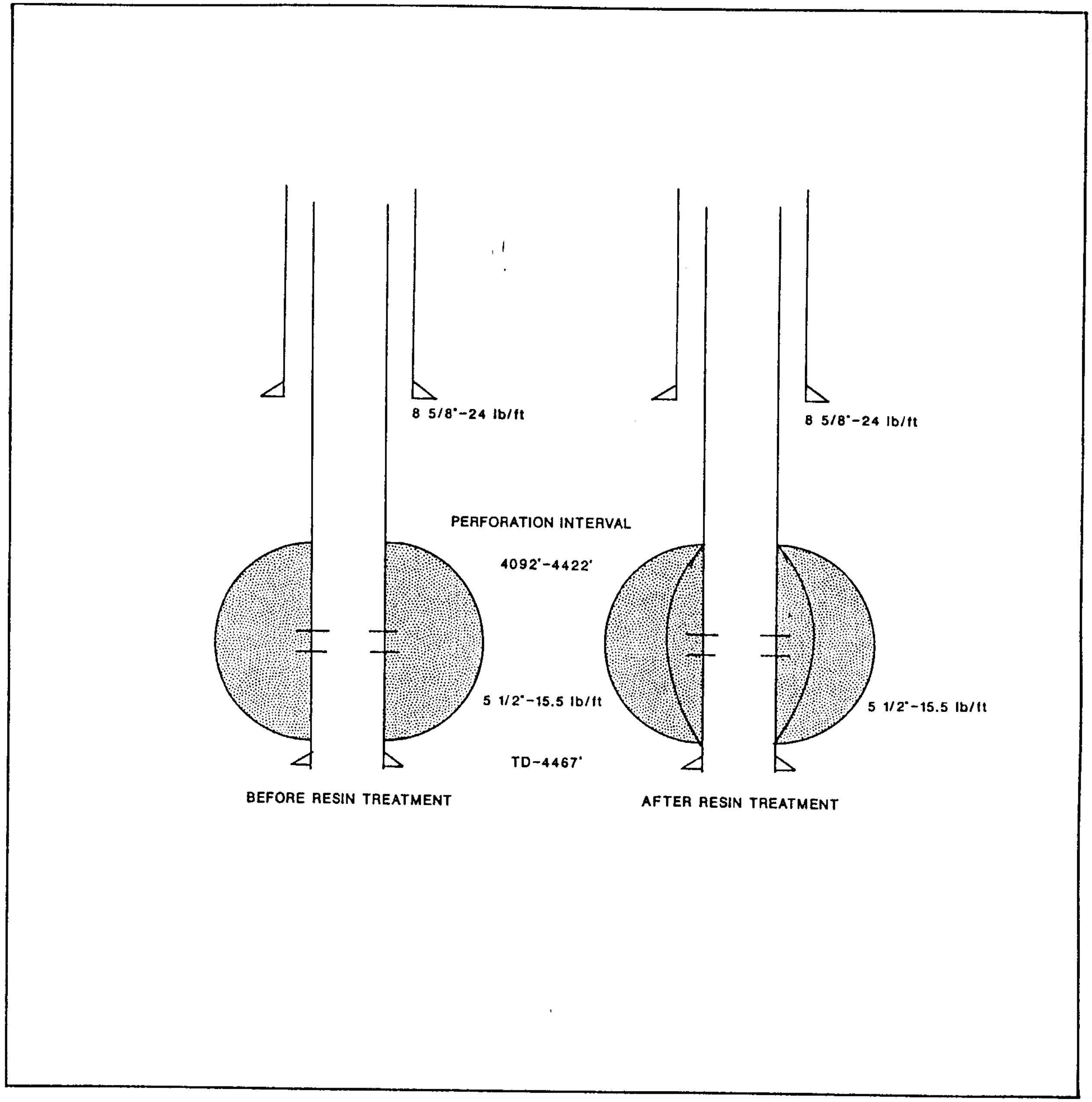

Figure 3 - Cased hole technique

NCU #824
OPEN HOLE TECHNIQUE

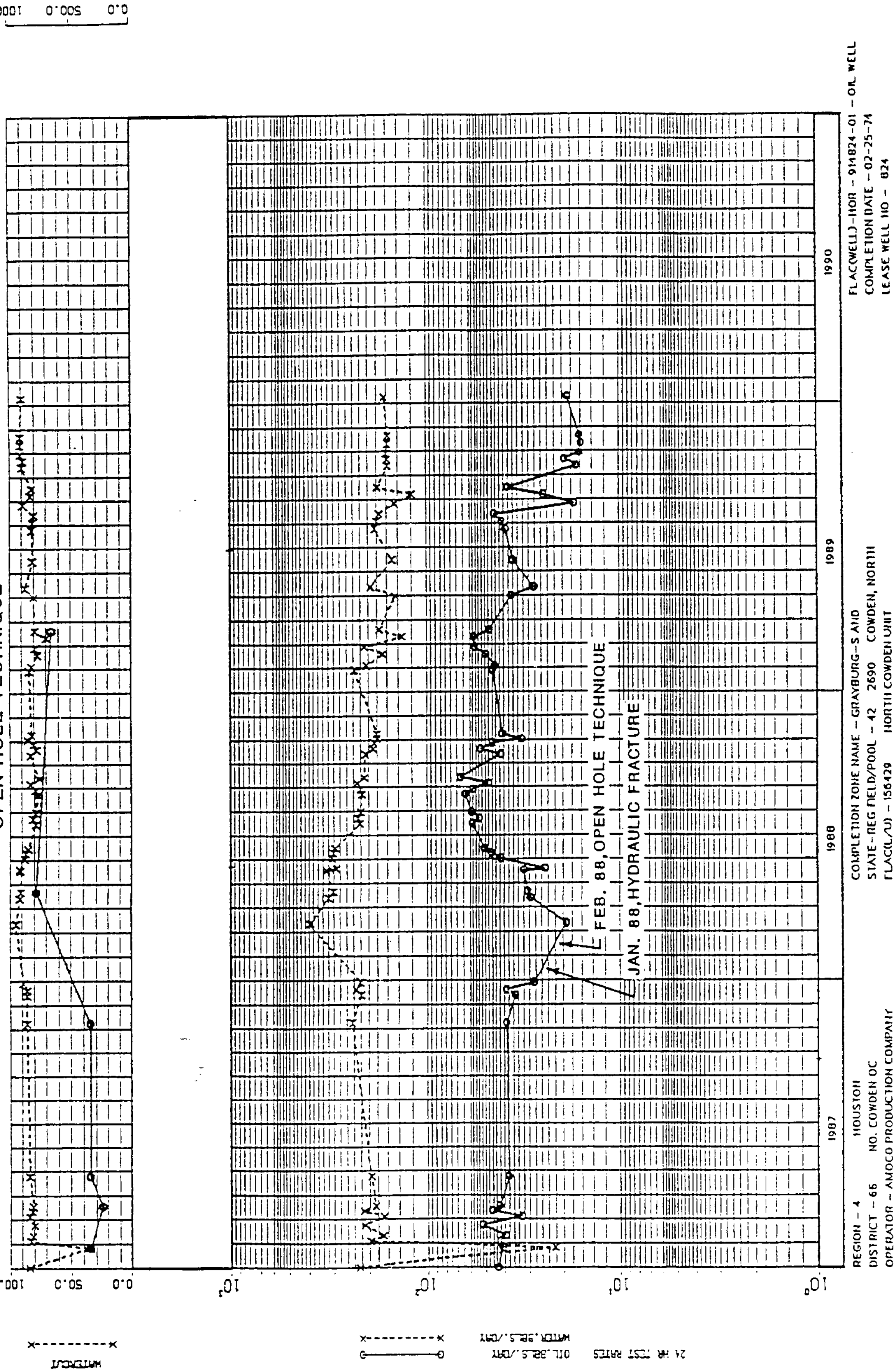

Figure 4

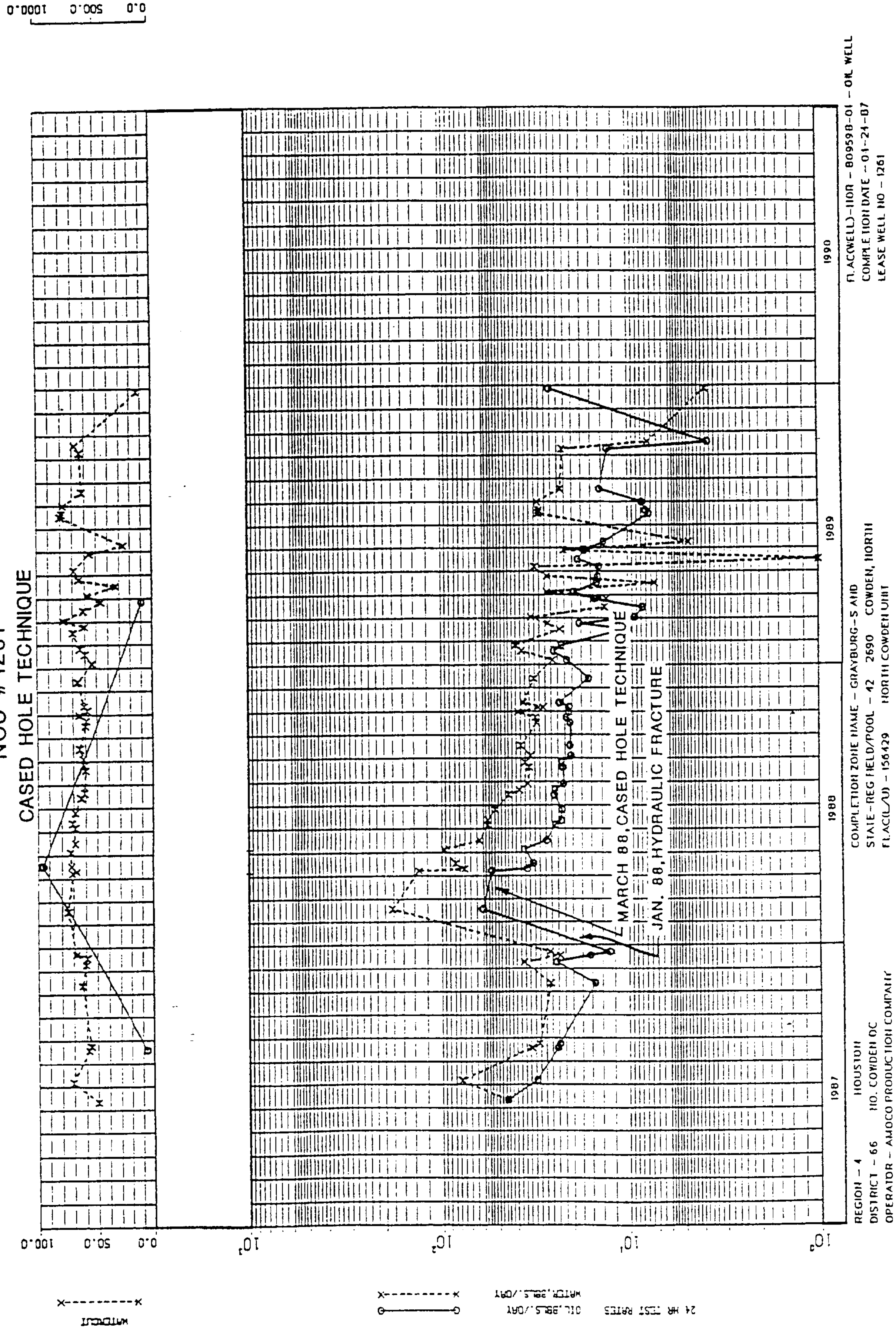
NCU #1261
CASED HOLE TECHNIQUE
MARCH 88, CASED HOLE TECHNIQUE
JAN. 88, HYDRAULIC FRACTURE
1987
1988
1989
1990
REGION - 4 HOUSTON
DISTRICT - 66 NO. COWDEN OC
OPERATOR - AMOCO PRODUCTION COMPANY
COMPLETION ZONE NAME - GRAYBURG-SAND
STATE-REG FIELD/POOL - 42 2690 COWDEN, NORTH
FLAC(LAU) - 156429 NORTH COWDEN UNIT
FLAC(WELL)-NOR - 809598-01 - OIL WELL
COMPLETION DATE - 01-24-07
LEASE WELL NO - 1261

Figure 5