APPLICATION OF HIGH STRENGTH PROPPANTS IN RELATIVELY SHALLOW AND HARD FORMATIONS

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ABSTRACT

The use of high strength proppants in wells that are deeper than 15,000' is not new to the oil industry. Utilization of these expensive proppants; however, in shallow (±8400'), hard formation wells is new to the industry, especially in the West Texas area.

Four wells in the Calvin (Dean) Field of Glasscock County, Texas are currently undergoing a comparison test. Two wells were fractured using 20/40 mesh sand while the other two wells were fractured using 20/40 mesh sintered bauxite. The justification to use bauxite in individual treatments, the preliminary results, and current well performances are discussed in this paper.

INTRODUCTION

The intent of this paper is three-fold. First, a brief description of the reservoir and the rationale used to justify the sintered bauxite project will be discussed. Second, a review of the work that Sohio has done with the proppant comparison tests in the subject wells will be presented. And last, the most recent production results from the wells and Sohio's conclusions will be given.

BACKGROUND

Sohio operates 44 leases, consisting of 19,000 acres and 117 producing wells in the Calvin (Dean) Field of West Texas. Production from the Calvin (Dean) Field, shown in Figure No. 1, was begun in 1965, and remains as an important part of Sohio's activity in West Texas. Wells in the field produce from the Dean formation (±8400'), which is usually considered a lower member of the Leonard Group of the Permian Period. Dean wells are typically completed with a restricted number of perforations, 10 to 15, to allow some amount of limited entry during fracture treatments.[1] A sample Gamma Ray - Neutron Log, with Dean perforations indicated, is shown in Figure No. 2.

Reservoir characteristics of the Dean formation are very similar to the better known Spraberry formation which overlies it. These reservoirs are often referred to as "the world's largest reserve of nonrecoverable oil". The Dean formation is sometimes called a siltstone and not a sandstone, because of its hardness and lack of permeability. Total porosity ranges from 5% to 9%. The compressive strength of the rock is about 12,600 psi/ sq.in. compared with 5,000 psi/ sq.in. for concrete blocks and 7,250 psi/ sq.in. for Berea sandstone. The matrix permeability of the rock is very low, averaging only 0.003 md. to 0.05 md. Production from the reservoir; however, is possible because of the existence of a natural fracture system. Ultimate recoveries, producing rates, and drainage efficiency for each well are dependent on the joining of these fractures with the wellbore, usually by a hydraulically created fracture that is propped with 20/40 mesh sand.[2] While the reservoir fluids travel through these fractures, they contain only a small amount of the original oil in place.

Due to the hardness of the reservoir rock and the increasing closure stress, crushing of the 20/40 mesh fracturing sand can occur. Closure stress can be calculated using the following equation:

$$\text{Closure Stress} = \text{Frac. Gradient} \times \text{Depth} - \text{Bottom Hole Producing Pressure} \qquad (1)$$

At initial reservoir conditions in the Calvin (Dean) wells:

$$\begin{aligned}\text{Closure Stress} &= (0.65) \times (8400') - 3000 \text{ psi} \\ &= 2460 \text{ psi}\end{aligned}$$

At abandonment, assumed to be 500 psi reservoir pressure:

$$\begin{aligned}\text{Closure Stress} &= (0.65) \times (8400') - 500 \text{ psi} \\ &= 4960 \text{ psi}\end{aligned}$$

As can be seen, closure stress increases significantly while depletion of the reservoir occurs.

Microscopic examination of sand recovered from Sohio wells in this field, prove that crushing of the 20/40 mesh sand has, indeed, been occurring. Photographs of the crushed sand are shown in Figure No. 3. It is the belief of many operators in the field that the crushing is caused more by the point-to-point loading of the individual sand grains than by the relatively low closure stresses. This type loading occurs because the reservoir rock is too hard to allow for sand grain embedment and the proppant is too brittle to deform, illustrated in Figure No. 4. Brittle proppants, such as silica sand, deform only slightly in a hard formation before failing at the points of contact.[3]

Sohio felt that if sand crushing could be minimized, higher producing rates and better drainage efficiencies could be achieved. This could be accomplished by one of two ways. First, the sand concentration in the created fracture could be increased so the loading on individual sand grains would be lower. Increasing the sand concentration has usually led to premature "screen outs" due to the low injection rates. Also, Sohio employs a "pillar frac" procedure which relies on the placement of sand in columns or pillars in the fracture system while it is being held open by hydraulic pressure.[4] An example of a "pillar frac" treatment is shown in Table No. 1. The second method of reducing sand crushing is to utilize a higher strength proppant. Such proppants as glass beads, steel shot, and aluminum pellets have been used in recent years in deep wells because of the high overburden pressures. None of these proppants has proven to be satisfactory. Research into this problem by Exxon Production Research Co., yielded a new high strength proppant, sintered bauxite.[3] This new proppant has the desirable property of toughness, i.e. strong but not as brittle as sand. Sohio chose to evaluate this proppant in a shallow, hard formation, the Calvin (Dean), based on its excellent crushing resistance, Figure No. 5.

The decision was made to use the sintered bauxite on two wells to be drilled on the J.C. Bryans "B" lease, wells no. 5 and no. 7. The other two wells to be drilled on the lease, wells no. 6 and no. 8, would be fractured using the normal 20/40 mesh sand. The two bauxite wells were to be fractured using the identical procedure as the sand wells except that the 20/40 mesh sand would be subsituded with an equal weight of sintered bauxite. The locations of these four wells are shown in Figure No. 6.

Economic justification for the project was based on the assumption that more reserves could be recovered sooner by the use of the sintered bauxite. As shown in Table No. 2, the bauxite project would payout when 3,191 bbls. of oil were recovered above that which could be expected using the normal sand proppant. It should be remembered that an effective fracture treatment does not increase oil in place, but increases the amount of reserves that may be recovered.

WELL HISTORIES

The first well completed on the lease, well no. 5, was fracture treated on March 28, 1982 with a "pilar frac" procedure and 55,440 lbs. of sintered bauxite as the propping agent. The well was potentialed after all load oil was recovered, on April 15, 1982 for 105 BOPD, 20 BWPD, and 122 MCFGPD. The well has not yet ceased flowing but should be put on pump in the near future. A pressure build-up test was not obtained on this well due to mechanical difficulty after the well was completed. The well is flowing 21 BOPD, 5 BWPD, and 79 MCFGPD now.

The next well to be drilled on the lease, well no. 6, was fractured on April 12, 1982 with the same "pilar frac" design, except that 76,500 lbs. of 20/40 mesh sand was used as the proppant. The well was potentialed on May 1, 1982 for 90 BOPD, 20 BWPD, and 81 MCFGPD. The reservoir pressure determined from a 96 hour build-up test was 3080 psia. The well was put on pump July 17, 1982 and is currently producing 24 BOPD, 10 BWPD, and 75 MCFGPD.

Well no. 7 was drilled next and fractured on May 21, 1982 with the same "pilar" technique and 72,000 lbs. of sintered bauxite was used. On June 17, 1982, the well was potentialed for 52 BOPD, 10 BWPD, and 60 MCFGPD. The 96 hour pressure build-up test showed a reservoir pressure of 3020 psia. The well was put on pump October 8, 1982 and production is now 56 BOPD, 16 BWPD, and 100 MCFGPD.

The last well to be drilled on the lease, well no. 8, was fractured on June 4, 1982 using the same "pilar frac" schedule and 43,100 lbs. of sand as the proppant. It was potentialed on June 21, 1982 for 90 BOPD, 15 BWPD, and 90 MCFGPD. A reservoir pressure of 3127 psia was indicated from a 96 hour pressure build-up test. The well was put on pump November 1, 1982 and is currently producing 75 BOPD, 19 BWPD, and 106 MCFGPD.

The completion data from these four wells is summarized in Table 3.

FIELD RESULTS

Production graphs for the four subject wells are shown in Figure No. 7, No. 8, No. 9, and No. 10. Several key items are marked on the graphs, indicating when the wells were put on pump, when the wells were shut-in for bottom hole pressure tests, and the current cumulative oil production from each well.

Only a limited amount of production history is currently available on the four wells used in this project. All of the incremental benefits to be derived from using the sintered bauxite may not be fully realized for several years, as the reservoir pressure is reduced and closure stress reaches its maximum.

To evaluate the success or failure of the project thus far, one question should be answered. Was the initial production from the bauxite wells increased, i.e. were the same reserves produced in a shorter length of time when compared to the sand fractured wells? In answering this question, it is clear that the bauxite wells did not have higher initial rates. The two bauxite wells averaged 79 BOPD initially while the two sand fractured wells averaged 90 BOPD. As for having a higher sustained producing rate, the two bauxite wells do have a slight advantage. The sand fractured wells in this area have recovered an average of 8,450 bbls. of oil during their first six months of production. The two bauxite wells recovered an average of 9,950 bbls. of oil, or 1,500 bbls. of oil more than the sand wells, during their first six months of production. This has been a source of encouragement for Sohio to continue evaluating high strength proppants in this field.

CONCLUSIONS

Sohio realized prior to beginning this project that the long term benefits from the use of the sintered bauxite might not be evident for a number of years. The information presented in this paper, though, is done in an effort to evaluate the preliminary results of the work. Production from the wells that were fractured using sintered bauxite, appears to be as great as production from comparable wells fractured using sand. Also, it has been shown that some of Sohio's older wells in the Calvin (Dean) Field suffer, to some degree, from crushing of fracture sand. There has been no evidence to date that any crushing has occurred in the two bauxite fractured wells. Sufficient encouragement has been found in this project for Sohio to continue its work with high strength proppants.

Since this project was begun, a new intermediate strength proppant, Carborundum's Carbo-Prop and Norton's Inter-Prop, has been introduced to the industry. Sohio has used this intermediate proppant in two new Calvin (Dean) wells in place of the sintered bauxite. Once again, the early results are encouraging, with several additional benefits. The new proppant is about 30% less expensive than the sintered bauxite and based on available information, the new proppant is about 80% as strong as bauxite, yet 40% stronger than sand, shown in Table No. 4. Also, this new proppant has an apparent specific gravity, 3.1, nearer to sand (specific gravity of 2.65) than the sintered bauxite which has a specific gravity of about 3.6.

The low reserves, 40,000 to 45,000 bbls. of oil, being realized by in-fill drilling in the Calvin (Dean) Field make economic indicators for future drilling marginal at best. Little incentive can be found for pioneering new ideas in these wells. Sohio; however, has experimented with high strength proppants during the past year in its new wells. Based on the early results from this work, Sohio will be considering the continued use of high strength proppants, such as sintered bauxite and Carbo-Prop, in fracturing future Calvin (Dean) wells.

REFERENCES

1. Hassebroek, W.E. and Waters, A.B.:"Advancements Through 15 Years of Fracturing",J. of Pet. Tech.(July,1964) 760-764.
2. Bucy, B. and Halepeska, B.:"Completion and Stimulation Programs in the Spraberry Trend of West Texas",presented at the Southwestern Petroleum Shortcourse,Texas Tech Univ.,April,1975.
3. Cooke,C.E.Jr.:"Fracturing With a High-Strength Proppant",J. of Pet. Tech.(Oct.,1977) 1222-1226.
4. Pugh, T.D. and Seglem, R.L.:"A New Fracturing Technique for Dean Sand",paper SPE 6378 presented at the SPE Permian Basin Oil and Gas Recovery Conference,Midland, Texas,March,1977.

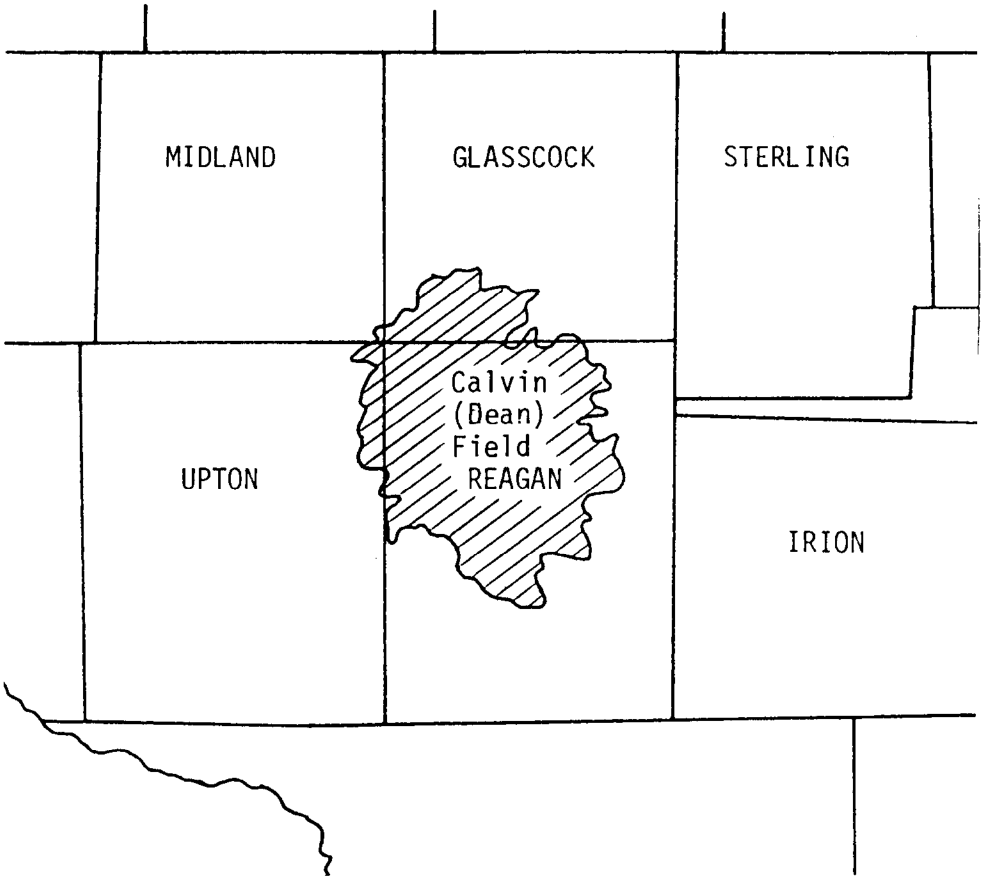


FIGURE 1 — CALVIN (DEAN) FIELD OF WEST TEXAS

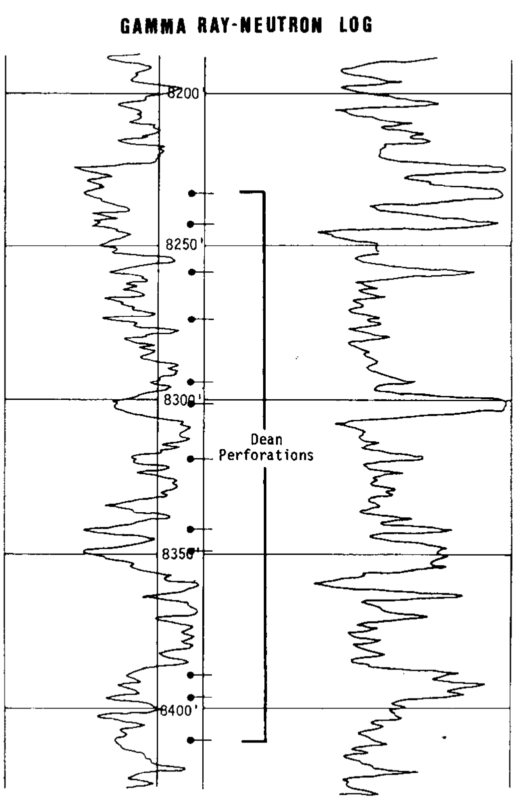
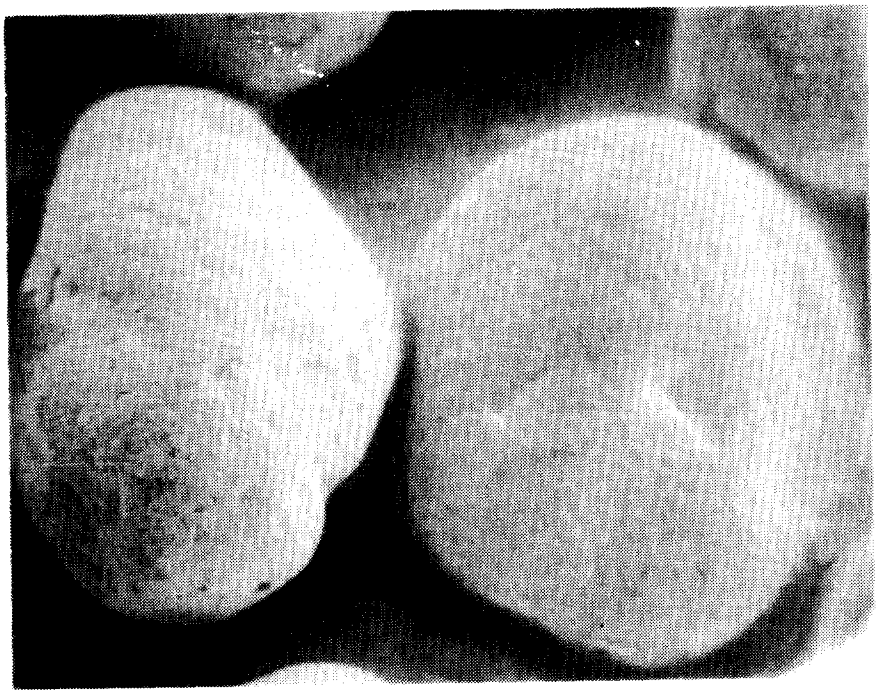


FIGURE 2 — TYPICAL GAMMA RAY - NEUTRON LOG FROM A CALVIN (DEAN) WELL



Ordinary 20/40 Mesh Frac Sand

Crushed Frac Sand, 100+ Mesh

FIGURE 3 — FRAC SAND FROM A CALVIN (DEAN) WELL

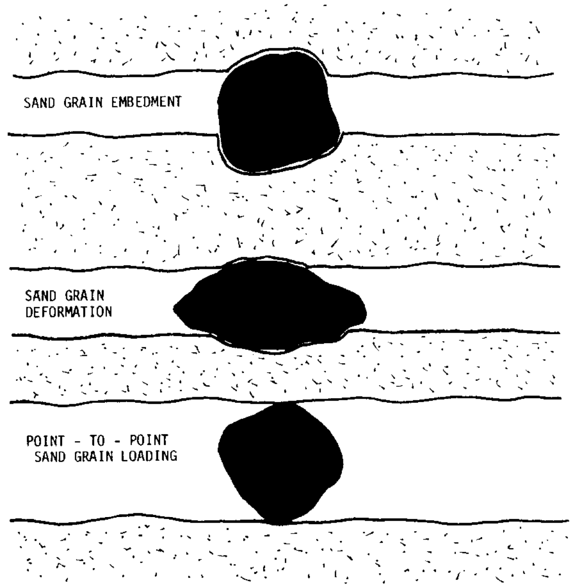


FIGURE 4 — DIFFERENT TYPES OF SAND GRAIN LOADING IN A FRACTURE

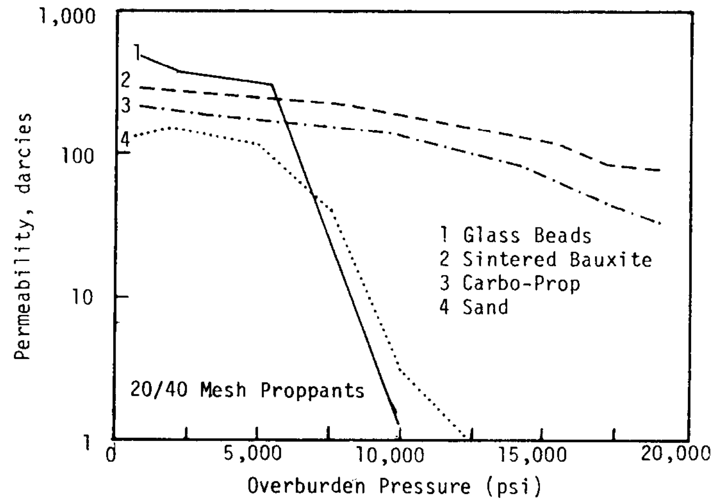


FIGURE 5 — PROPPANT STRENGTHS

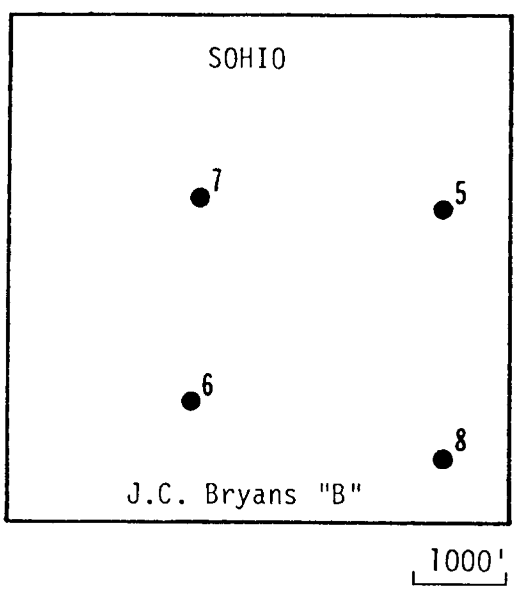


FIGURE 6 — LOCATION OF SUBJECT WELLS

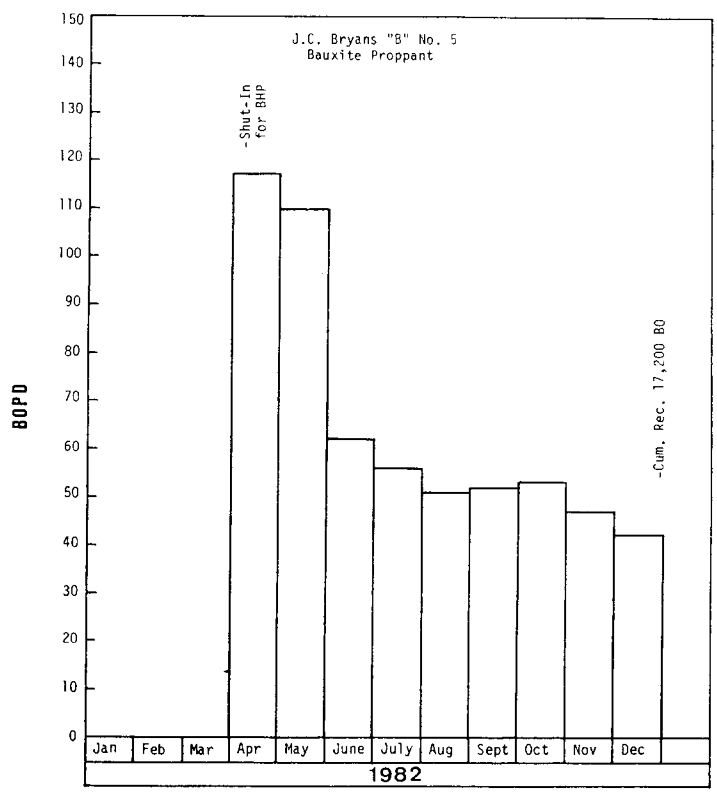


FIGURE 7 — PRODUCTION GRAPH FOR J.C. BRYANS "B" NO. 5

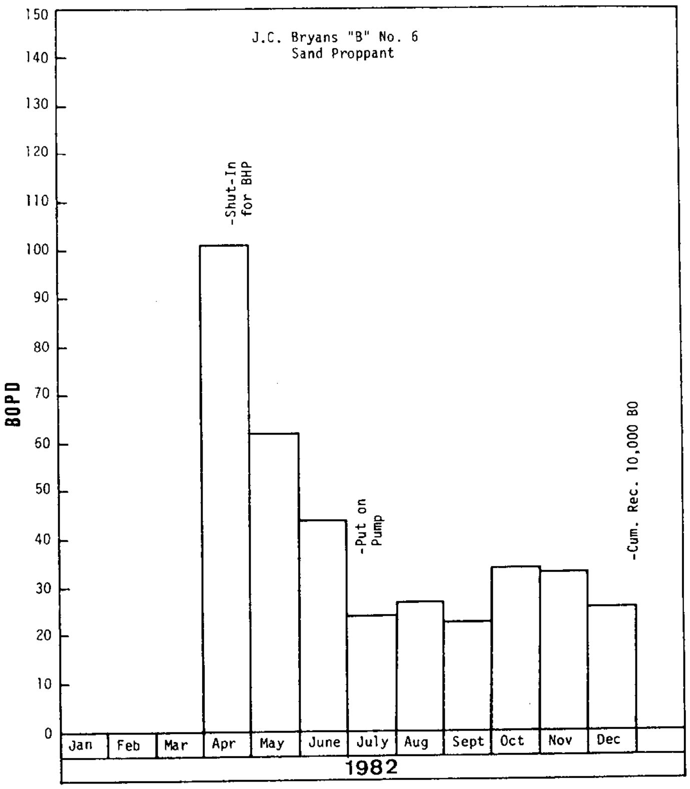


FIGURE 8 — PRODUCTION GRAPH FOR J.C. BRYANS "B" NO. 6

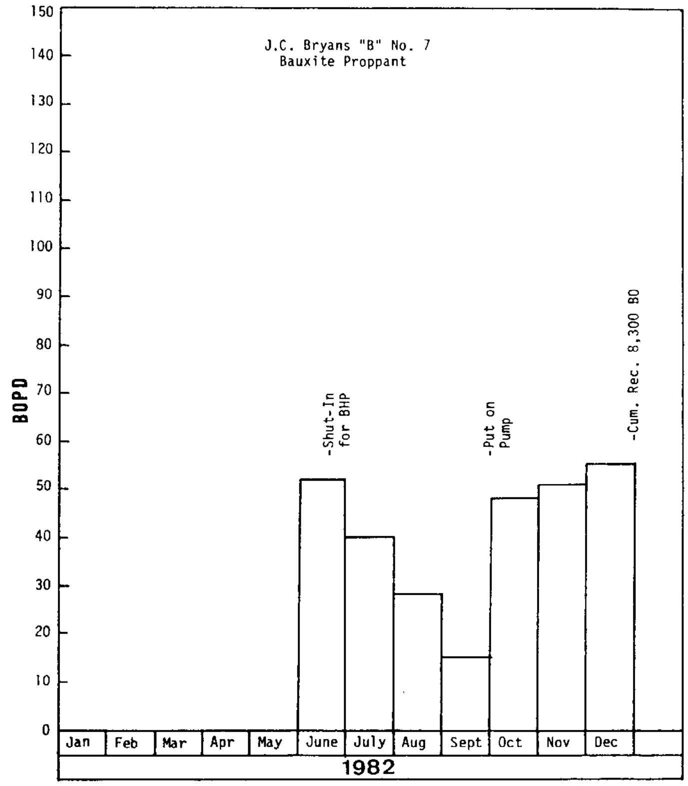


FIGURE 9 — PRODUCTION GRAPH FOR J.C. BRYANS "B" NO. 7

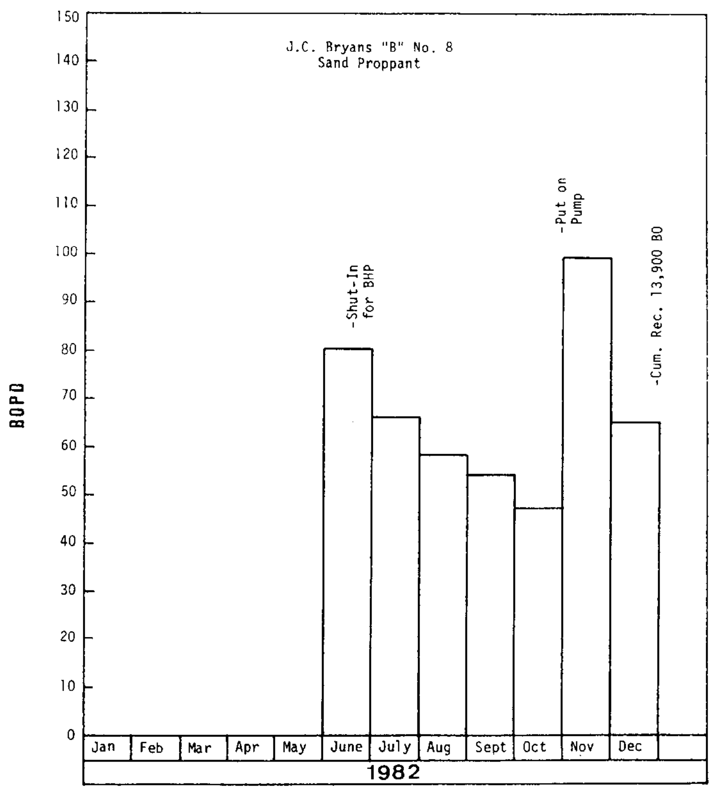


FIGURE 10 — PRODUCTION GRAPH FOR J.C. BRYANS "B" NO. 8

TABLE 1 — "PILLAR FRAC" PROCEDURE

FLUID		PROPPANT (Sand or Sintered Bauxite)			
Vol., gals.	Type	Concentration, ppg	Type	Total Amt., lbs.	Cum. Vol., gals.
16,200	Emulsion	0	(pad)	0	16,200
7,400	Emulsion	2.0	100 mesh	14,800	23,600
500	Emulsion	0	(spacer)	0	24,100
4,700	Crude	0	(spacer)	0	28,800
4,000	Emulsion	1.0	20/40 mesh	4,000	32,800
500	Emulsion	0	(spacer)	0	33,300
2,200	Crude	0	(spacer)	0	35,500
7,400	Emulsion	2.0	20/40 mesh	14,800	42,900
500	Emulsion	0	(spacer)	0	43,400
4,700	Crude	0	(spacer)	0	48,100
7,400	Emulsion	2.0	20/40 mesh	14,800	55,500
500	Emulsion	0	(spacer)	0	56,000
4,700	Crude	0	(spacer)	0	60,700
*7,400	Emulsion	3.0	20/40 mesh	22,200	68,100
500	Emulsion	0	(spacer)	0	68,600
4,900	Crude	0	(spacer)	0	73,500
*6,900	Emulsion	3.0	20/40 mesh	20,700	80,400
500	Emulsion	0	(displacement)	0	80,900
2,200	Crude	0	(displacement)	0	83,100

* Start at 2.5 ppg if needed due to pressure limitations.

TABLE 2 — PAYOUT OF HIGH STRENGTH PROPPANTS

	20/40 Mesh Proppants		
	Sintered Bauxite	Carbo-Prop	Sand
Cost of Proppant, $/ lb.	.88	.60	.056
Total Cost of Proppant, $	67,320	45,900	4,284
Cost Over Sand, $	63,036	41,616	-
*Reserves Needed for Payout, Bbl.	-3,191	2,107	-

* Based on an average net per bbl. of $19.75.

TABLE 3 — COMPLETION DATA FOR THE J.C. BRYANS "B" WELLS

	No. 5	No. 6	No. 7	No.8
Completion Data	3-28-82	4-12-82	5-21-82	6-4-82
Proppant	bauxite	sand	bauxite	sand
Initial Potential	105 BOPD	90 BOPD	52 BOPD	90 BOPD
Reservoir Pressure	-	3080 psi	3020 psi	3127 psi
Date Put on Pump	-	7-17-82	10-8-82	11-1-82
Current Prod., Jan. '83	42 BOPD	26 BOPD	55 BOPD	65 BOPD
Cum. Prod., to Jan.1, '83	17,200 BO	10,000 BO	8,300 BO	13,900 BO

TABLE 4 — COMPRESSIVE STRENGTHS

Material	Mesh Size	Approx. Compressive Strength, psi
Sand	10/20	4,000 - 5,000
Sand	20/40	6,000 - 7,000
Glass Beads	All	6,000 - 8,000
Bauxite	20/40	10,000 -12,000
Carbo-Prop	20/40	8,000 - 9,000
Berea	-	7,250
Dean rock	-	12,600