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INCREASED SECONDARY RECOVERY BY HYDRAULIC FRACTURING

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INTRODUCTION

Fracturing has become an important stimulation method both for production and injection wells in secondary recovery operations. The increased percentage of oil produced by secondary recovery makes studies of the effect of fracturing increasingly important.

REASONS FOR FRACTURING

There are several reasons why secondary recovery wells should be fractured. Fracturing often makes possible recovering more oil from the reservoir than could otherwise be produced. A reservoir's permeability is so greatly increased that a faster flow of fluid through the reservoir can be obtained under given differential pressures. This condition extends the reservoir's productive life.

In some cases fracturing reduces injection well operating pressures, perhaps eliminating the need for high pressure injection equipment. Fracturing often makes profitable oil recovery possible in a reservoir which otherwise could not be considered commercial. Such a situation may occur after prolonged waterflooding or early in the life of a water flood project.

SELECTING WELLS TO BE FRACTURED

Several factors should be considered in selecting wells to be fractured. After water injection is started, several months may elapse before the formation's void spaces are filled. Many operators use as a rule-of-thumb that a production well should be fractured if it has not responded satisfactorily after one and a half times the calculated fill-up volume has been injected into off-set wells. This rule-of-thumb has been used frequently, and, in most cases, the fractured wells have responded immediately.

Illustrations at end of paper

If an individual production well has begun to produce large amounts of water it should not be fractured. A fracturing treatment would probably increase water production, rather than oil production. However, a repair job [for example using latex-cement or plastic] may successfully shut off the water and make a fracturing treatment feasible.

In case of injection wells, fracturing treatments are often performed simply because the well does not accept water properly. This situation may occur when production wells are converted to injection wells or when new injection wells are drilled.

MULTIPLE FRACTURES

It is generally accepted that a vertical sweep is desirable in secondary recovery because of its greater efficiency. For this reason, fracturing treatments should be planned to provide multiple fractures, well spaced throughout the vertical thickness of the formation.

In most cases, a vertical fracture is probably more desirable than a horizontal fracture. If the upper or lower limits of the formation have undesirable characteristics, as for example, nearby water zones, vertical fractures would not be preferred.

Several methods are used to control fractures. The most common method is the use of temporary plugging agents. Such agents include naphthalines, gelled kerosines and rock salts. They are removed by either dissolving in formation fluids or by internal chemical reactions which cause them to break. A recent development in temporary plugging agents is the use of ball sealers to close perforations. These work by differential pressure and fall away from the perforation when the fluid flow is reversed.

TABLE NO. 1

COMPLETED WATERFLOOD DATA
BARTLESVILLE SANDSTONE

Curve No.	Acres Flooded	Thickness Feet	Bbl Oil Recovered by Waterflood Total	Per Acre	Per Ac-Ft	Water Injected Bbl	Cum. (Wtr. Inj. / Oil Prod.)	Flood Life Months
1	97	30	207,536	2,140	71.3	6,623,000	32	139
2	37	30	80,975	2,189	73.0	907,360	11	119
3	60	18	125,109	2,085	116.0	2,681,325	21	100
4	202	20	628,576	3,112	156.0	12,258,184	20	140
5	130	25	233,780	1,798	71.9	8,777,812	38	100
6	60	26	73,593	1,227	47.2	1,759,013	24	40
7	135	15	302,549	2,241	150.0	2,759,063	9	99
8	186	25	303,393	1,631	65.2	9,260,979	31	86
9	157	40	1,100,000	7,000	175.3	Unknown	-	195
10	135	30	333,706	2,472	82.4	5,080,554	15	80
11	1,010	30	3,830,000	3,790	126.3	Unknown	-	224
12	168	30	565,934	3,369	112.0	10,356,037	18	90
13	180	40	462,500	2,560	64.2	Unknown	-	216
14	44	25	62,389	1,418	56.6	733,691	12	82
15	128	30	246,021	1,922	65.0	2,026,126	8	66
16	130	30	482,000	3,588	123.6	11,102,847	23	135
17	208	22	392,213	1,886	86.0	4,127,646	11	106
18	40	25	185,497	4,637	185.5	2,427,132	13	118
19	100	12	116,208	1,162	96.9	1,324,400	10	93
20	34	28	150,877	4,438	158.3	6,038,414	40	103
21	220	40	1,125,608	5,110	121.8	19,600,000	17	249
TOTAL AND AVERAGES	3,465	27.2	11,008,464	2,846	105.0	107,843,583	19.6	123

TABLE NO. 2

FLOOD LIFE vs ULTIMATE WATERFLOOD RECOVERY
[Months vs Per Cent]

Curve No.	First Response	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
1	4	23.0	35.0	48.0	58.4	65.6	72.0	75.6	87.0	100.5	139.0
2	8	20.0	27.5	34.0	40.1	47.3	55.2	65.5	79.9	98.0	119.0
3	3	8.3	13.3	18.4	23.3	28.4	33.5	40.1	47.4	63.0	100.0
4	6	12.5	18.9	25.0	31.6	38.6	46.2	55.0	65.9	83.0	140.0
5	4	15.3	20.8	23.9	27.2	32.0	28.2	45.8	54.2	68.4	100.0
6	4	8.2	10.8	13.3	15.7	18.3	21.0	24.8	28.5	32.0	40.0
7	3	10.6	15.0	19.5	23.8	28.2	32.5	38.7	45.6	58.6	99.0
8	7	11.2	16.8	22.0	27.1	33.3	40.9	47.5	53.8	64.2	86.0
9	6	7.6	9.2	10.8	12.3	14.0	16.6	21.7	26.8	49.5	195.0
10	11	11.0	13.3	15.9	18.3	20.8	24.8	28.9	33.0	44.0	80.0
11	6	13.4	20.4	25.8	31.1	37.0	43.1	52.7	64.8	95.2	224.0
12	6	8.8	11.3	13.9	16.8	19.9	23.0	26.0	37.4	54.9	90.0
13	4	16.3	23.0	29.0	35.0	42.1	50.2	62.3	82.9	121.5	216.0
14	31	33.0	37.4	42.0	46.4	50.5	54.6	59.3	65.3	72.3	82.0
15	8	11.2	15.0	20.1	25.3	30.0	35.0	40.0	45.0	51.3	66.0
16	5	12.7	17.7	21.5	25.2	30.2	35.7	43.0	54.0	81.2	135.0
17	7	19.3	25.1	30.7	35.2	39.9	45.6	52.4	60.8	72.8	106.0
18	2	11.7	17.0	22.9	27.0	38.0	52.5	62.2	71.4	88.5	118.0
19	2	15.4	23.1	29.5	33.9	38.4	44.5	52.0	62.5	75.4	93.0
20	6	10.5	15.2	19.9	24.0	28.4	33.5	41.0	51.1	67.5	103.0
21	2	31.8	40.6	47.8	55.2	64.0	75.3	89.6	111.9	169.0	249.0
Avg., Mos.	6.4	14.85	20.30	25.42	30.14	35.47	41.61	48.29	58.53	76.70	122.86
Avg., Yrs.	0.53	1.24	1.69	2.12	2.51	2.96	3.47	4.02	4.88	6.39	10.2

To obtain multiple fractures, the fracturing fluid should have high fluid loss and sufficient viscosity to carry sand properly at the intended injection rate. Such a fluid will rapidly leak away into the fracture walls, causing sand grains to stop within the fracture. The fracture becomes filled with sand which acts as a plugging agent to divert the fracturing fluid into other fractures.

A third factor in obtaining multiple fractures is the use of high sand concentrations. Such concentrations cause bridging within the fracture, inducing multiple fractures in the same way as does rapid fluid loss.

CASE HISTORIES

Fig. 1 is a production decline curve of a well completed in 1951, which was placed under flood in Dec., 1952. Its response to water flooding was unsatisfactory. In Dec., 1955, this well was fractured, and production immediately jumped from 4 bbl of oil per day to about 130 bbl of oil per day. Production gains from this pool have been, for the wells thus far treated, in excess of 4,000 bbl of oil per day. No communication between wells has been observed, and water-oil ratios have actually improved following fracturing.

Fig. 2 is a performance curve from an individual producing pattern. Production declined from mid-1953 until early in 1954, when the first injection well was fractured. A second injection well was fractured late in 1954. Each of these treatments helped to increase water injection, total liquid production and oil production.

Fig. 3 is a reservoir performance graph illustrating how fracturing affects reservoir oil production. This reservoir was placed under flood in 1951. In May, 1954, production began to decline steadily. In November the offset injection wells were fractured, and production wells immediately responded with substantial increases. The additional oil recovered due to fracturing can be seen by extrapolating the decline curve beginning in May, 1954, and comparing it with the actual performance curve.

SUMMARY

Hydraulic fracturing has increased oil production and water injection rates in secondary recovery fields. No detrimental effects have been observed following fracturing. Optimum fracturing techniques call for high-fluid-loss fracturing fluids, high sand concentrations, and the use of temporary plugging materials to obtain multiple fractures.

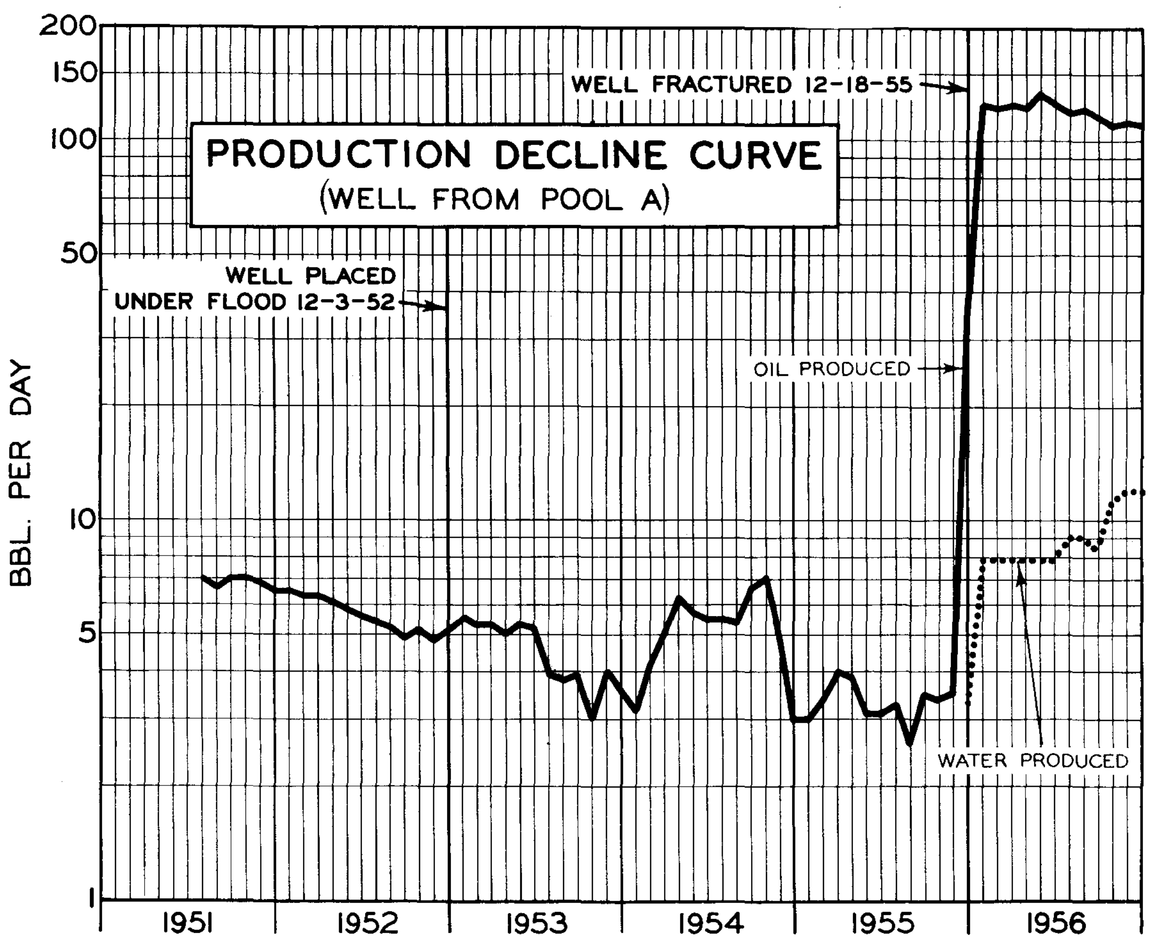
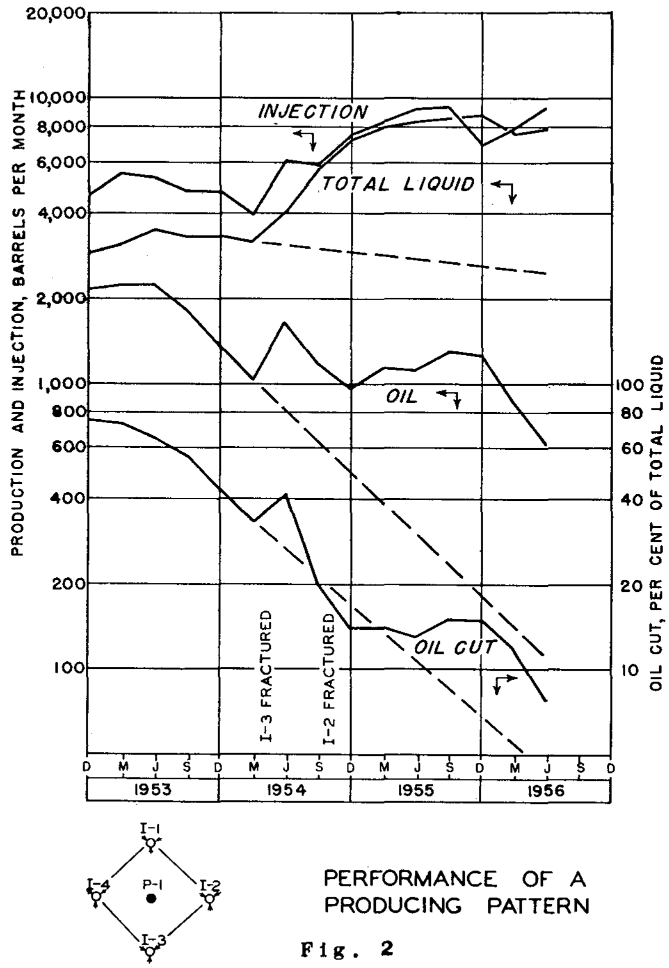


Fig. 1



PERFORMANCE OF A PRODUCING PATTERN

Fig. 2

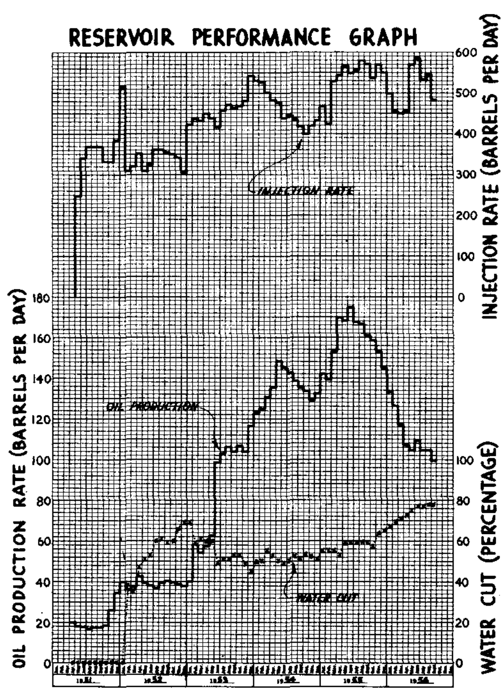


Fig. 3