New Polymer Treatment Increases Oil Recovery and Profits

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INTRODUCTION

Until lately, most polymer projects appearing in the literature were individual case histories. Actual oil recovery was reduced by what might have been recovered from a conventional flood (using one of several prediction methods) and the remainder called "Polymer Oil". These case histories added important data to industry files and were very useful when an operator considering polymer treatment had a reservoir which matched one of the detailed studies.

This article brings out important features which four early polymer projects nave in common. The projects represent a wide spread in rock properties, geography and fluid mobilities (Table I). In spite of these differences, they acted alike on three counts:

1. Input wells which stayed on vacuum long after calculated fill-up showed pressure soon after polymer treatment was started. This pressure remained stable after polymer treatment was stopped.
2. Producing wells affected by polymer-treated inputs showed definite changes in producing water/oil ratios (WOR's).
3. There is a correlation between extra oil due to polymer ("Polymer Oil") and the total amount of oil in place at the start of secondary.

By considering these three points when screening existing projects for polymer treatment, much guesswork can be eliminated. Accurately-sized polymer treatments keep costs within estimates. Extra oil expected from the program can be predicted and economics for any potential project which falls into the range represented by these four pilot studies can be projected.

TABLE I.

	Flood A	Flood B	Flood C	Flood D
Permeability Average — md	4.3	90	235	1200
Permeability Range — md	1.1-11.2	30-150	10-2440	100-2500
Porosity	16.8	21	15	20
Connate Water — % PV	45	25	35	25
Residual Oil — % PV	21	20	20	25
Oil Viscosity — cps	3	7.5	6	2.5
Formation Temp. °F	90	100	85	95
Formation Type	Bartlesville Sand	Lansing-Kansas City Lime	Spar Mt. (Rosiclare) Sand	Strawn Sand
Formation Thickness	16'	10'	10'	30'
Original Oil in Place (BAF)	640	1040	812	1000

INPUT WELL RESPONSES

Figure 1 shows the behavior of injection well 2-1 (Flood B) before, during and after polymer treatment. The well had taken 130,000 bbls on vacuum and four weeks (10,000 bbls) after the start of treatment, began showing pressure. Eleven months after treatment was stopped, the pressure still remained at 500 psig.

FIGURE 1.—Injection Well (2-1) Behavior Before, During, and After Polymer Treatment.

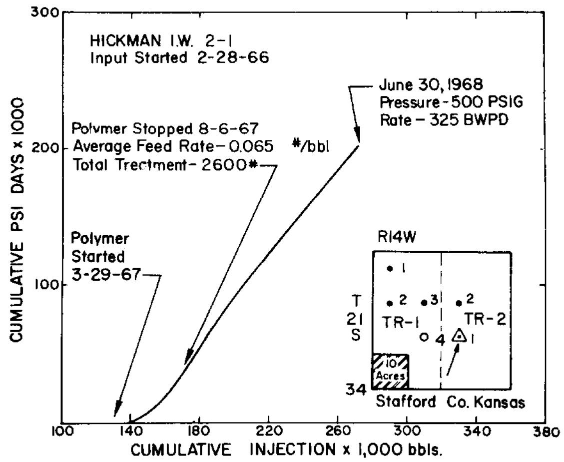
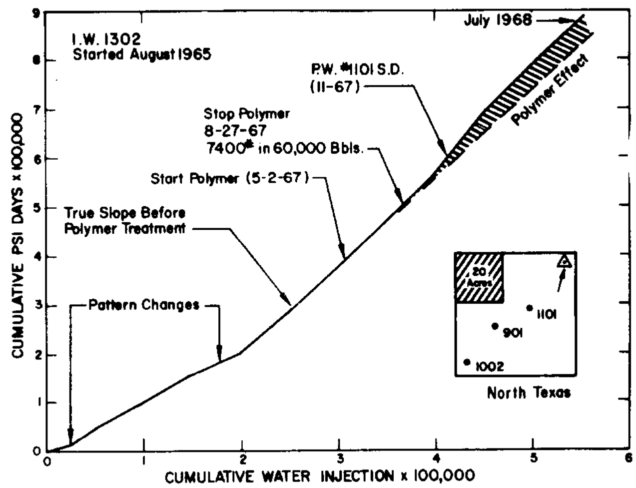


Table II shows three input wells which had been on vacuum prior to polymer treatment. In each case, water had broken through to nearby producing wells. After polymer treatment, the slope of each psi day/bbl curve held constant.

An example of what can be expected from polymer treatment of input wells that are cycling water at pressures only slightly below normal is shown in Fig. 2. Average input rate for injection well 1302 was 17 BPD per foot of sand. The slope changed slightly from 1.5 psi days/bbl before treatment to 1.7 psi days/bbl afterward. Actual wellhead pressure increase was less than 100 psig.

FIGURE 2. — Plot of Cumulative Pressure vs Cumulative Injection Showing Effect of Polymer.



Moore W1-2 (Flood A) followed the same pattern with pressure increasing from 800 psig at the start to 1000 psig six months later. Although the slope change was greater — from six to nine psi days per bbl. — about half of the total change could be traced to increasing input rates from six to eight BPD per foot during this same period

Laboratory work with diluted polymer solutions in cores and sand packs clearly shows that pressure increases are to be expected. Cores having permeabilities under 100 millidarcies (md) and sand packs with permeabilities over 7000 md have been tested with similar results.

TABLE II.

Flood	Input Well	Input Volume on Vacuum [1] bbls.	Polymer #454 Treatment	Slope PSI Days/bbl	Final Injection Pressure [2] PSIG
A	Aagard W1-8	50,000	2000# in 30,000 bbls.	2.2	500
B	2-1	130,000	2600# in 40,000 bbls.	1.75	650
C	Tracey #1	11,500	300# in 2500 bbls.	3	200

[1] To the start of treatment

[2] At the end of treatment

On the injection side, changes due to polymer treatment can range from dramatic, when wells are on vacuum, to barely noticeable when pressures are near normal.

PRODUCING WELL RESPONSES

The real justification for polymer treatment is greater total oil recovery. Any producing side change that takes the form of less water, more oil or a drop in the WOR will permit more recovery ahead of the economic limit.

Figure 3 details WOR changes and oil production increases following polymer treatment of input well 2-1 (Flood B). It is important to note that response at producing well 1-2 and the typical drop in lease WOR were well underway when 1-3 was shut down. Extra oil in the tanks due to polymer totaled 9115 bbls through December, 1968. Projected Polymer Oil is 20,805 bbls through December, 1970.

FIGURE 3.—Polymer Effect on Oil Production and WOR.

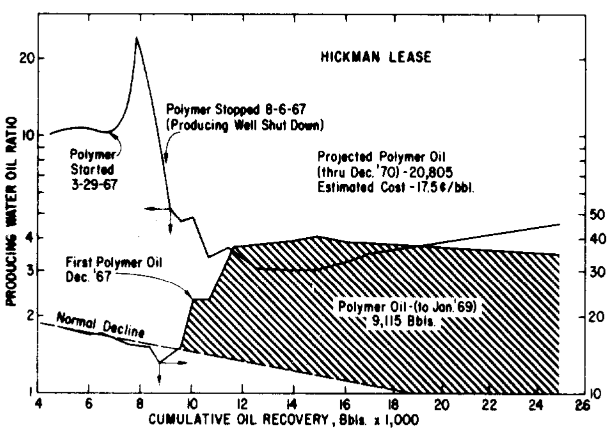
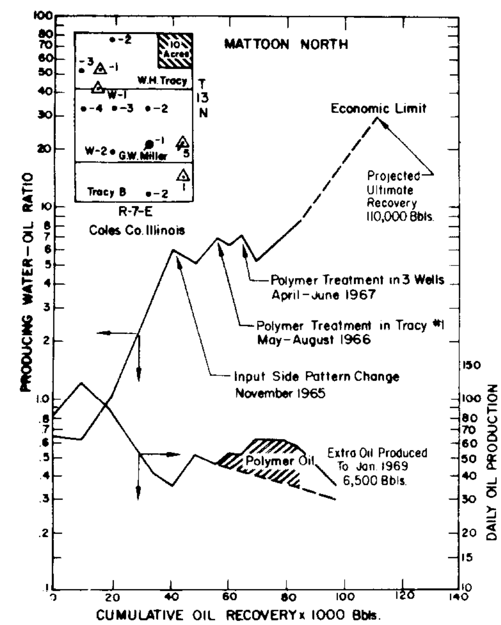


Figure 4 (Flood C) covers producing well responses to polymer treatment of three input wells in 1967 after a favorable one-well pilot during mid-1966.

Shutting-in one input and starting another definitely helped oil recovery during late 1965 and the first quarter of 1966. Production started to level off in April, 1966 and a polymer pilot was started in May. Response was favorable with the direct north offset (Tracey #2) increasing production from 4 to 14 BOPD while WOR dropped from 1.2 to 0.6. The first increase in production came three months after polymer treatment was started.

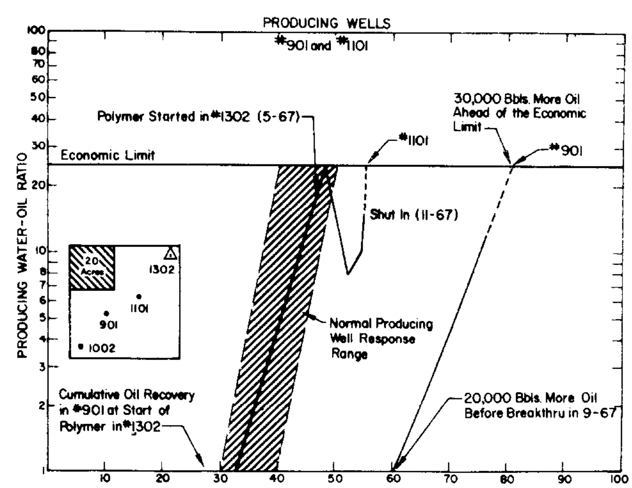
FIGURE 4. — Oil Well Response to Polymer Treatment.



With all three input wells receiving polymer from April through June of 1967, production rose steadily from 45 BOPD at the start to 60 BOPD in October. Extra Polymer Oil produced through December 1968 totaled 6500 bbls. Projected Polymer Oil recovery through December 1970 is 10,000 bbls.

Figure 5 (Flood D) compares two polymer-affected producing wells with reference wells

FIGURE 5. — Comparison of Polymer-affected Wells With Reference Wells.



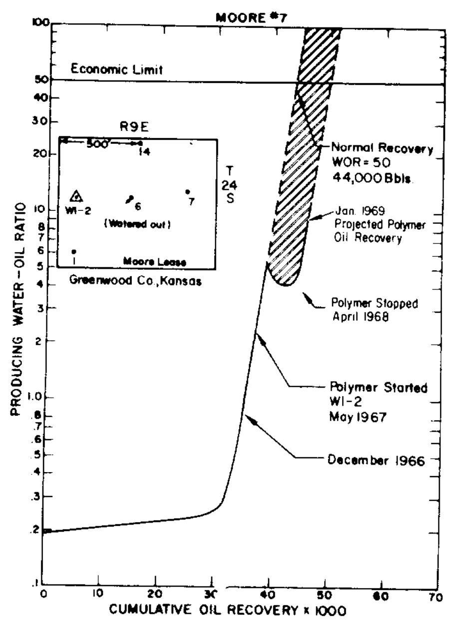
typical of the rapid rise in WOR that occurs after breakthrough in this reservoir. With all the drive from input well 1302 going southwest, the first polymer-affected well (#1101) showed a break in the WOR curve a month after treatment was started. Although it was kept pumping above the economic limit for a short time, the shift in WOR of producing well 1101 contributed 4000 bbls of Polymer Oil.

The second S.W. offset (#901) produced 20,000 bbls more oil ahead of breakthrough than other wells in this area of the field. Normal wells produced 10,000 bbls from breakthrough to the economic limit with the best being 15,000 bbls. Producing well 901 will make at least 20,000 bbls after breakthrough for the best performance so far.

The third S.W. offset (#1102) is far enough along to tell that it will be an excellent well. WOR went above one in February 1968 at cumulative oil production of 60,000 bbls. Through August, oil recovery was 84,350 bbls with WOR still below five.

Polymer-affected producing wells on the Moore Lease (Flood A) also showed definite WOR curve breaks or reversals. Figure 6 charts the behavior of Moore #7 after polymer injection in WI-2. This well has already added 8000 bbls of Polymer Oil to Moore Lease totals.

FIGURE 6.—Producing Weil Behavior (Moore No. 7) Following Polymer Injection (WI-2).



Laboratory Work

A laboratory setup designed to flood three cores of different permeabilities at the same time clearly demonstrates greater oil recovery when polymer-treated brine is used. One run showed oil recovery to breakthrough improved by 18 per cent of pore volume when a Polymer #454 solution was added in a way that would best duplicate field work.

When permeabilities to water are rerun after flooding cores in parallel with polymer, the core with the highest initial value shows the greatest per cent decrease. Polymer held in the core has very little effect on permeability to oil, the degree of reduction being less than one-tenth of that noted for brine. Here, again, laboratory work confirms polymer pilot observations on two important points:

1. Polymer treatment should change producing water/oil ratios.
2. Polymer treatment early in the life of a flood should permit greater oil recovery ahead of breakthrough.

POLYMER OIL COSTS

It is one thing to use prediction methods to figure Polymer Oil for a flood that received polymer-treated water from the start and quite another to take a stable condition close to the economic limit, apply polymer and total up production responses to clearly show the amount of extra oil production.

Table III details the cost of Polymer Oil for each project and shows how projected Polymer Oil recoveries relate to total oil in place at the start of secondary.

Column 2 includes mixing and feeding expense as well as delivered polymer cost. Column 3 is the amount of extra oil due to polymer that has been produced and sold with Column 4 listing the cost/bbl. of this oil. As production continues, Column 3 values should approach those in Column 5 with a proportionate drop in the cost of Polymer Oil.

The correlation which is of most interest at the present time appears in Column 8. When extra oil due to polymer comes mainly from better volumetric sweep, it should be possible to express this Polymer Oil as a percent of total oil in place at the start of secondary recovery.

These early projects show that a properly-designed polymer treatment program can increase oil recovery by an average of 5.4 per cent of the TOTAL oil in place at the start of flooding. The cost of this "extra oil" can approach 14.6¢/bbl.

TABLE III. PILOT PROJECT SUMMARY

1 Flood	2 In Place Polymer Cost	3 Actual Polymer Oil Produced Thru Dec. '68	4 Cost of Polymer Oil Produced	5 Projected Polymer Oil and Date	6 Cost of Polymer Oil Projected	7 Oil in Place @ Start of Secondary	8 Projected Polymer Oil as % of Column 7
A	$ 1680	10,800	15	14000 12/69	12	110,000	12.7
B	$ 3650	9,115	40	20800 12/70	17.5	505,000	4.1
C	$ 2200	6,500	34	10000 12/71	22	490,000	2.0
D	$11420	70,000	16	85000 6/69	13.4	1,320,000	6.4
TOTALS	$18950	96,415	19.6	129800	14.6	2,425,000	5.4

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