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Report No. BERC-0003-9

MASTER

EL DORADO MICELLAR - POLYMER PROJECT

TECHNICAL LETTER FOR APRIL, 1976

Summary of Activities for April, 1976

The well stimulation program has continued to appear favorable initially, however, the injection rates have tended to decrease slightly. In an attempt to maintain the high level of injectivity obtained after the acid treatment, four wells were acidized with a larger acid volume. The results are currently being reviewed.

A total of 25,578 and 24,207 barrels of pretreatment fluids were injected into the Chesney and Hegberg patterns, respectively.

Work to control bacteria activity will continue into next month. No conclusions have been reached yet. The chemical tracer testing has been underway since April 19. This work will be continuing through May and into June. As of the end of April, there had been no breakthrough of tracers into any of the eight production wells or two observation wells.

Four oil recovery flow tests have been conducted to investigate the effectiveness of the latest Shell design in displacing residual oil from El Dorado cores. These tests were made using 0.1, 0.25, 0.5, and 2.0 pore volumes of chemical slug with Kelzan F polymer and the drive water and preflush specified by Shell. It was found that residual oil saturation can be reduced to approximately five percent of the pore volume with preflush and continuous injection of chemical slug through two-inch diameter stacked cores about ten inches long.

Other chemical work has included a study of the solid residue formed in the Shell micellar concentrate, chemical analyses for the wax content of oil, and preparation of cores for wettability tests.

The wettability tests were run by personnel in the Bartlesville Energy Research Center of ERDA. These tests were designed to determine any wettability changes due to preheating of cores up to 120 degrees F. The wettabilities of the heated cores were somewhat less negative than those of the unheated cores.

DISCLAIMER

An injectivity test using a soluble oil pretreatment has been planned for mid-May. Bottom-hole pressures for the monitoring wells were measured April 13 and 14. All pressures have increased considerably since December, 1975.

Performance prediction work has included a comprehensive study of reservoir sweep and oil recovery versus well rates, additional work on polymer simulation, and a review of Hall and Muskat plots.

ENGINEERING AND OPERATIONS

Well Stimulation

Based on the results of the Xylene - Hydrochloric Acid - Hydrofluoric Acid - Hydrochloric Acid treatments, it was decided to stimulate four additional wells with the same basic type treatment, only with a larger volume. MP 201 and 211 were acidized for the first time, whereas, MP 116 and 203 had been acidized with 500 gallons HCl acid and 1000 gallons HF acid before. Below is a summary of acidizing with 850 gallons HCl - 1700 gallons HF - 850 gallons HCl:

Well	Rate Before B/D	Press (PSI)	Rate After B/D	Press (PSI)	Rate Now B/D	Press PSI
MP 116	37	185	152	90	155	140
MP 201	32	205	153	165	141	175
MP 203	70	195	131	200	150	175
MP 211	2	180	119	200	123	185

The larger HCl - HF - HCl treatment will be considered for future stimulation efforts.

Bacteria Control

A chlorine gas was introduced at the pump station last month as a rate of 8 ppm for Bacteria Control. Bacteria cultures run on the fresh water downstream chlorine injection indicated that the bacteria count was 100 - 1000 colonies per millileter. Since the chlorine residual at the injection plant was at the maximum rate (0.3 ppm), it was decided to maintain the chlorine rate as a partial bacteria treatment. Increasing the chlorine rate would probably reduce the bacteria to an acceptable level (10-100 colonies/mi), however, it would be incompatible with polyacrylamides during the mobility buffer stage. It is planned to add a chlorinated phenol at the plant for complete bacteria control.

MONTHLY PRODUCTION REPORT

Well No.	Monthly Volumes, Bbls. Oil	Water	Days Prod.	Cumul. Since Start Oil	Water	Date Started
MP 112	36	2,100	29	141	7,058	11/17/75
MP 114	72	960	29	291	2,959	"
MP 122	61	1,769	29	170	5,191	"
MP 124	24	3,036	29	180	9,495	"
Chesney						
MP 207	61	927	29	332	3,317	"
MP 209	48	1,824	29	150	6,056	"
MP 217	24	1,944	29	121	6,991	"
MP 219	49	1,825	29	152	6,777	"
Hegberg						

MONTHLY INJECTION REPORT (Pretreatment)

Well No.	Barrels Injected	Injection Press. psig	Days on	Cumulative Inj. bbls.	Date Started
MP 106	1,612	195	29	6,007	11/17/75
MP 108	2,562	195	29	8,335	"
MP 110	4,526	90	29	12,373	"
MP 116	3,008	100	28	9,063	"
MP 118	1,507	195	16	6,272	"
MP 120	4,047	195	29	13,554	"
MP 126	1,654	195	29	9,491	"
MP 128	4,176	195	29	11,095	"
MP 130	2,486	195	29	6,529	"
Chesney	25,578			82,719	
MP 201	2,444	200	28	10,938	"
MP 203	2,369	200	28	8,846	"
MP 205	2,662	200	29	8,720	"
MP 211	1,869	200	28	9,303	"
MP 213-226	1,389	200	17	6,717	"
MP 215	3,531	200	29	9,244	"
MP 221	4,355	200	29	11,721	"
MP 223	2,676	200	29	8,568	"
MP 225	2,912	200	29	9,068	"
Hegberg	24,207			83,125	
Total Project	49,785			165,844	

MONTHLY PRODUCING WELL TEST REPORT

Well No.	Actual Vol. Produced Oil	Water	Hours Tested	Pump Size	Stroke Length	Strokes Per Min.
MP 112	TR	160	24	1½	42"	17
MP 114	5	65	24	1½	32"	13½
MP 122	5	160	24	1½	42"	16
MP 124	0	250	24	1½	42"	14½
MP 207	10	80	24	1½	22"	13½
MP 209	TR	145	24	1½	42"	16
MP 217	TR	95	24	1½	42"	16
MP 219	5	150	24	1½	42"	15

RESEARCH SUPPORT

Chemical Selection and Support

Tracers. The tracer testing and analysis was begun in April. Tracer injection began at 5:00 p.m. on April 19, 1976, starting with 600 lb. of ammonium thiocyanate. The remaining tracers were injected at two per day. Day one, the first day with all the tracers injected, was April 23. The total amount of tracers and the wells involved are summarized below.

Tracer	Amount	Wells
Ammonium thiocyanate	600 lbs.	MP-126, 130, and 203
Formaldehyde	8 drums (55 gal)	MP-106, 110, 221, and 225
Sodium bromide	300 lbs.	MP-116, 120, 211, and 215
Ammonium nitrate	1500 lbs.	MP-128, 201, and 205
Potassium iodide	400 lbs.	MP-118 and MP-213
Sodium salicylate	600 lbs.	MP-108 and MP-223

At the start of injection, samples were collected every six hours. After about ten days, the collection rate was once a day at 1:00 p.m. Samples are being collected from the eight production wells and the two observation wells with pumping units. These wells are MP-112, 114, 122, 124, 131, 207, 209, 217, 219, and 227. Observation wells MP-131 and MP-227 were produced continuously until May 5, 1976, due to the high sampling frequency.

Qualitative and quantitative analysis was carried out on each sample collected (one sample is the ten individual samples collected at one time). The qualitative analysis has been done to check for nitrate, iodide, salicylate, formaldehyde, and thiocyanate. Quantitative analysis has been done to check for bromides and chlorides. As of April 30, there was no breakthrough of any of the tracers in question.

The table below shows the changes in salinities with time for the ten wells tested. As can be seen, low salinity breakthrough has occurred at observation well MP-131. It is presently at about 80 percent of its initial salinity and should be logged in the near future.

Well	April 20, 1976 Starting Salinity (NaCl) (avg. of first 11 samples) mg per liter	Salinity Ending April 30, 1976 mg per liter	Current Salinity / Starting Salinity Percent of Starting Salinity
MP-112	91,870	90,120	98.1
MP-114	90,730	89,590	98.7
MP-122	92,370	90,880	98.4
MP-124	93,600	91,960	98.3
MP-131	77,000	71,680	93.0
MP-207	91,550	91,080	99.5
MP-209	90,850	89,420	98.4
MP-217	96,140	94,300	98.1
MP-219	94,240	92,780	97.4
MP-227	95,230	93,800	98.4

Oil recovery flow tests. Four flow tests were conducted to investigate the effectiveness of Shell's process in displacing residual oil from El Dorado cores. Flow tests were conducted on two-inch diameter stacked El Dorado cores (four plugs in series) having a total length of approximately ten inches and mounted in a Hassler type flow cell.

A summary of the results is shown in table #1 "Chemical Flood Performance," Results as shown in the table are based on the pore volume determined by extraction which is equivalent to the summation of water volume and residual oil volume determined by weight loss. Corrected values are also shown in parentheses and explained in a footnote on the table.

Residue in Shell Micellar concentrate. Shell micellar concentrate was prepared according to Shell's recommended procedure of March 9, 1976, and centrifuged for approximately 20 minutes at 18,000 rpm. The dried solid residue from centrifuging was approximately 2.9 weight percent of the micellar concentrate. Energy dispersive X-ray fluorescence analysis (an X-ray spectrograph) indicated the residue to be sodium sulfate.

In another experiment the effects of centrifuge speed on the mass of dried residue obtained by centrifuging Shell concentrate were examined: The results are tabulated below.

Centrifuge Speed and Time	Dried Residue Obtained Weight Percent
5,000 rpm for 10 min	1.06
10,000 rpm for 10 min	2.39
15,000 rpm for 10 min	2.66
18,000 rpm for 20 min	2.66

On this basis, there would be approximately 8.8 lb. of dried residue per barrel of micellar concentrate.

In an attempt to determine if filtration might be an acceptable alternative to centrifuging, the Shell concentrate was filtered through a filter apparatus which contained three 90 mm diameter filter papers in series. The final filter was a 0.45 micron millipore filter. The mass of the dried residue on the two coarse filters indicated that roughly three weight percent of the Shell concentrate was retained on the filter papers. Additional filtration work is needed to evaluate the effectiveness of filtering the concentrate in the field. Gravity segregation followed by filtration may be an efficient method of removing the Na_2SO_4 in the field.

Other chemical work. Work during April, 1976, has also included an analysis of a heater-treater scale and of three oil samples from laboratory experiments. The oil analyses were done to determine if wax had precipitated from oil into cores. The molecular distribution of the crude oil determined in these tests indicated that there was little change in the composition of the oils (i.e., there was essentially no wax pick up detectable by analysis of the oils from the heated and unheated cores).

A memo was sent to G. L. Davis on April 15, concerning the nature of suspended solids found in various samples of filtered El Dorado lake water. The total solid content was found to be much higher than reported on February 9. The organic content was found to be substantially higher.

Work has continued on the physical model of the El Dorado Demonstration Flood that will be displayed in the public section at the International Petroleum

Exposition in Tulsa.

Coring and Core Analyses

Wettability measurements. Wettability measurements on eight native-state core plugs (3/4 inch diameter by 32 mm long) from well MP-114 were made by ERDA personnel during April. These measurements were performed in an effort to determine if heating (which presumably would cause any wax which might be present to redissolve into the crude oil) the core plugs which contain formation brine and formation crude oil (at residual saturation) would noticeably alter rock wettability. ERDA measured wettability by the method of Donaldson, Thomas, and Lorenz (Society of Petroleum Engineers Journal, March, 1969, pp 13-20). All of the core plugs were drilled from two-inch diameter by 2½-inch plugs. These plugs were then cut into a "top" and a "bottom" portion (each portion was about 1¼ inches long). All of the core plugs ("top" and "bottom" portions) were saturated with Chesney brine. However, the beaker which contained Chesney brine and the "top" portion core plugs were placed in an oven at 125 degrees F and left overnight.

The wettability results reported by ERDA personnel are:

Unheated Cores		Heated Cores	
Sample No.	Wettability	Sample No.	Wettability
114B-641.0	-0.55	114T-641.0	-0.33
114B-641.9	-0.48	114T-641.9	-0.30
114B-641.6	-0.42	114T-641.6	-0.38
114B-642.9	-0.58	114T-641.8	-0.33

On the scale used, -1.0 is completely oil wet, +1.0 is completely water wet, and 0.0 corresponds to an intermediate wettability.

Donaldson, et al, stated that aged cores are generally oil-wet, which is in agreement with the work of other investigators. If "aged" means that the cores were drilled a year or so earlier, then these cores are "aged" (well MP-114 was completed on March 27, 1975.) However, the core was sealed in plastic at the well site within approximately one hour. The wettability data should be viewed accordingly.

Other core work. Steady-state relative permeability tests are continuing on high permeability samples from well MP-124. El Dorado produced fluids are being used in these tests.

Four observation well cores, MP-131, MP-132, MP-227, and MP-228 have been received.

Formation Injectivity

Planning and preparation have been underway for an injectivity test using soluble oil as a pretreatment. This test is expected to commence in mid-May using a well in the Hegberg lease.

Pressure Transient Test

On April 13-14, 1976, bottom-hole pressures were measured in the monitoring wells on the Chesney and Hegberg patterns. The data were to be used to calculate average pattern pressures, injection and production wellbore damage condition, and for computer modeling. All of the pressures were found to have increased considerably since December, 1975.

All the wells had been closed in at the surface and were opened only for the time required to run a pressure gauge to bottom and retrieve it. No lubricator was used, and the well was vented to the atmosphere while running the gauge to bottom. This allowed the pressurized gas column at the top of the casing to escape which caused all the measured bottom-hole pressures to be low. Therefore, the pressures measured are in error and represented the minimum bottom-hole pressures which could have existed at that time.

A simple and inexpensive method of measuring bottom-hole pressures without venting the well or using a lubricator is currently being developed.

Performance Prediction

Polymer flow simulation. One-dimensional runs made with Intercomp's polymerflood simulator were matched to a second, more accurate simulator in order to estimate what value to use for the parameter which controls numerical dispersion.

Based on the results of these runs, two-dimensional runs were then made to evaluate the polymer slug design proposed by Shell. The table below presents a summary of the results. Using a value of 30 lb. polymer adsorbed per acre-ft., the maximum polymer viscosity drops from an initial value of 80 cp to 39 cp after injection of 0.75 pore volume of polymer and drive water. The drop in viscosity is due to mixing of the first polymer increment with water in the oil bank ahead of the slug and with the more dilute polymer solution which follows the initial increment.

MAXIMUM POLYMER VISCOSITY VS. PORE VOLUME INJECTED

Shell Design with Adsorption = 30 lb polymer/ac-ft.

Pore Volumes Injected	Maximum Polymer Viscosity, cp
0.0	80
0.2	64
0.4	53
0.6	44
0.75	39

Sweep and oil recovery versus well rates. A study of the influence of the relative well rates on reservoir sweep and oil recovery for the project was made. Eleven cases are being investigated. The base case is a single five-spot in the center of a large array of repeating five-spots. A large scale project expansion should give results similar to the base case. Other cases include an isolated five-spot with 1 to 1 total injection to production ratio, an isolated five-spot with a 4 to 1 ratio, the entire El Dorado project with a 2 to 1 ratio, the entire El Dorado project with the average well rates that result from our planned constant pressure operating conditions (1.04 to 1 ratio), and the entire project with the stabilized rate operating conditions (1 to 1 ratio).

Plots of streamlines and flood fronts were prepared for each case. The major differences in these plots are in the regions outside of the confines of the five-spot patterns. The cases with large injection-production ratios have numerous streamlines that flow away from the patterns. In the cases with this ratio near one, most of the streamlines that initially flow away from the patterns eventually curve back to a production well. Within the confines of the patterns, the streamlines and fronts for most cases looked similar to the base case. The planned operating conditions case and the stabilized rate case have especially good agreement with the base case in these confined regions.

The streamlines that flow through regions outside the pattern before curving back to a production well indicate that a portion of these external regions will be swept by injection fluid. A computer program that estimates the total volume of reservoir pore space swept was written. This program calculates the cumulative amount of original reservoir fluid produced as a function of either time, cumulative injection, or cumulative total production. This amount of original reservoir fluid produced is a measure of the reservoir pore space that is effectively swept. The curves output by this program show that the reservoir volume swept for some of the cases is greater than the total reservoir pore volume within the confines of the pattern. This effect is well known for a balanced, isolated five-spot. Modeling predictions show that some exterior pore volume will be swept if the planned relative well rates are used for the project. However, this excess pore volume swept will be a smaller percentage of the total confined pore volume than the percentage excess pore volume for a balanced, isolated five-spot.

Most of the excess oil production due to this sweep of exterior pore space occurs late in the project life. In addition, the excess pore volume will be swept by a relatively small quantity of chemical slug. Thus, the oil recovery from the regions outside of the confines of the patterns will probably be less than the oil recovery from the confined pore volume. The percentage increase in oil recovery due to the sweep outside the confines of the project injection patterns will probably be less than the percentage increase in swept pore volume due to these effects. The primary objection to this outside sweep is that the increased oil recovery will make the results of the project optimistic. Presently, a program to quantitatively calculate the effects of this outside sweep on oil recovery is being developed. This program will eliminate the optimistic effects of outside sweep when scaling up project results to large scale flood.

Other performance prediction work. Modifications have been completed that make the superposition-of-line-source solutions program more flexible. The new program allows the well rate or pressure specifications to change with time. For any given time period, the user may either specify all well rates or all flowing bottom-hole pressures. Rates may be specified for some time periods and flowing bottom-hole pressures for other periods.

During a meeting with Shell, the vertical sweep used in slug size calculations was discussed. Subsequently, the core analysis of well MP-223 was used to compute what percentage of the section would receive at least a 12 percent chemical slug when the total slug volume is computed assuming a 70 percent overall vertical sweep. The results indicate that approximately 50 percent of the section would receive a 12 percent or greater chemical slug. To get more coverage would require a very much larger slug volume.

A review of the Hall and the Muskat plots was made. Muskat plots usually provide an estimate of $k_w h$ and skin factor for each injector. They do not appear to be very useful for the El Dorado injection wells, however. This is probably due to the plugging of the wells and to well interference. Thus, drawing of Muskat plots will be discontinued.

Hall plots normally provide a skin factor for injection wells. Skin factors at three different times were calculated and compared to previously determined values. The results were reported in a memo to the Project Manager and Research Project Leader dated April 29, 1976.

TABLE I

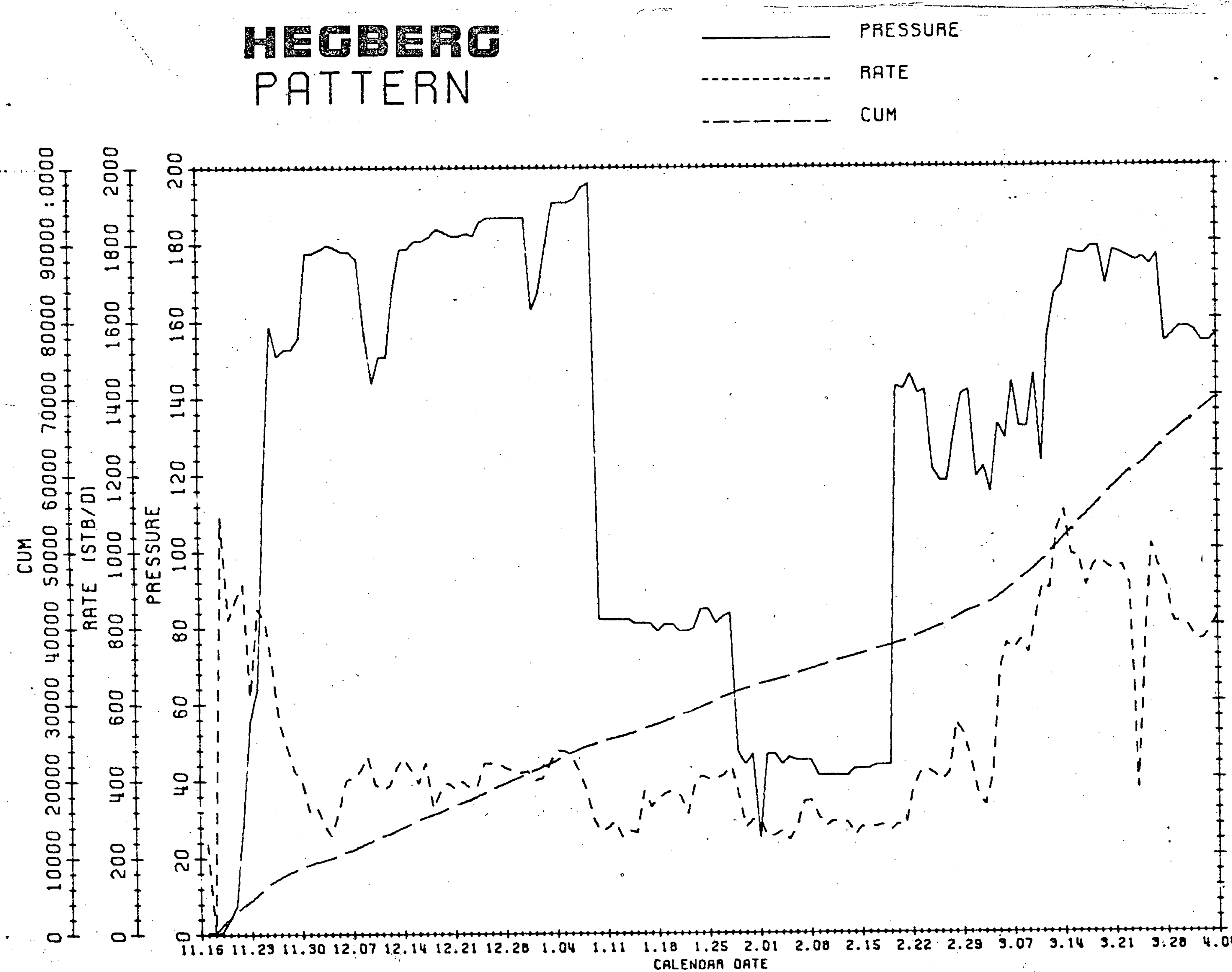
CHEMICAL FLOOD PERFORMANCE

	Test Number			
	1	2	3	4
Core Data, Identity	Well MP-114	Well MP-114	Well MP-114	Well MP-114
Dimensions, cm	5.08 x 29	5.08 x 26.84	5.08 x 26.84	5.08 x 26.6
Porosity, PV (pore volume)	0.271	0.269	0.250	0.266
K_{air}, md (extracted avg.)	306	369.5	236	366.5
K_w at S_{or}, md	34.9	41.8	27.5*	50.0
S_{or}, PV	0.390	0.406	0.388	0.42
Preflood, Volume Injected, PV	0.40	0.40	0.40	0.40
Chemical Slug, Volume Injected, PV	2.0	0.513	0.110	0.262
Polymer Drive, Volume Injected, PV	0.7	0.7	0.7	0.7
Flow Rate, ml/hr	6.25	6.25	6.25	6.25
Frontal Advance Rate, ft/day	0.90	0.90	0.97	0.91
Performance Data **				
S_{orf}, pore volume fraction	0.084 (0.051)*	0.148(0.108)	0.273 (0.219)	0.211 (0.178)
Oil Recovered, percent original oil in place	78.6 (84.5)	63.6 (68.2)	29.4 (31.9)	49.72 (53.3)

* Calculated from individual core permeabilities and not measured over the whole stack.

** Pore volume (determined by the Boyle's law expansion method) showed about 10 percent increase in pore volume. Also, it was speculated that there was some weight loss of sand grains during the extraction method; this was considered as oil in determining the residual oil. It was assumed that almost 3.368 gm is lost per stack (which amounts to 4 ml of oil). Taking these corrections in consideration, final oil recoveries and residual oil saturations are shown in parenthesis.

HEGBERG
PATTERN



CHESNEY PATTERN