"BERC-0003-5"

Contract No.
E(34-1)-0003

EL DORADO MICELLAR - POLYMER PROJECT

TECHNICAL LETTER FOR DECEMBER, 1975

Summary of Activities for December, 1975

The primary field activity for December has been operating the Injection Plant during the period of extreme freezing weather. Another prime concern has been the severe loss of injectivity experienced in the first two weeks of operation. A total of 12,170 barrels and 15,720 barrels has been injected in the Chesney and Hegberg patterns, respectively. This is a composite average of 50 barrels per day per well which is about one-half to one-third the desired injection rate.

Chemical selection and support work has included the following areas: mobility flow tests, surfactant and polymer testing, injectivity and chemical sensitivity flow tests, oil displacement tests, and support work relating to the field laboratory and the low injectivity problems.

Steady-state relative permeability data have been measured on two native-state core samples. A paper entitled "Core Analysis Study for the El Dorado Micellar-Polymer Project" was prepared for a Society of Petroleum Engineers meeting this spring.

A final summary of directional permeability is being prepared. The summary is to be the basis for a second paper at the Society of Petroleum Engineers meeting in March, 1976. Bottom-hole pressures were measured in each monitoring well in December to help evaluate possible causes for the low injectivity.

Computer simulations have been used to match the project injection and production rates. Very good agreement between observed and calculated rates was obtained for Kh values of 878 md-ft for the Chesney lease and 493 md-ft for the Hegberg lease.

DISCLAIMER

CONSTRUCTION

Injection Plant

Construction of the Injection Plant is essentially complete. There have been freezing problems associated with the fresh water filter skid, therefore, an insulated building has been ordered to house the skid. No major changes are anticipated in the design of the Injection Plant at this time.

ENGINEERING AND OPERATIONS

Pattern Injectivity and Well Stimulation

The injection rate was held to 100 barrels per day (B/D) for the first week, however, the second week the wellhead pressure increased to the "Caution" level (0.74 psi per foot) for fracture extension. After the maximum wellhead pressure was reached, the individual well rates in both patterns decreased sharply from approximately 100 B/D per well to 50 B/D per well.

Several meetings were held to discuss the cause(s) and solution(s) of the injectivity problem. It was concluded that there were several possible causes to the loss of injectivity and the first step would be to swab fluids back from MP-#120 to analyze for suspended solids, and water incompatibility (scale). The water analysis indicated that 16 percent of the solids were soluble in an aromatic solvent (Xylene) and 61 percent are soluble in 15 percent hydrochloric acid. The sample also contained eleven percent barium sulfate which was insoluble. Based on the analysis, it was decided to solvent-acidize MP #118, #129 and #203. These wells were treated with 100 gallons Xylene followed by 750 gallons 28% hydrochloric acid, 7.5 gallons acetic, and 37.5# citric acid. The results are listed below:

Well	Rate Before	WHP Before	Rate After	WHP After	Rate Now
#118	22	200	47	200	25
#120	65	200	90	210	114
#203	14	210	45	200	23

Further evaluation and recommendations will be continuing next month.

MONTHLY INJECTION REPORT

Well	Bbl.	Cum. Inj.	WHP	Days On	Remarks
106	795	1583	180	31	
108	1009	1829	170	31	Acidized 12/23/75
110	3042	4416	130	31	
116	642	1520	170	31	
118	1020	2013	170	31	
120	1462	2375	185	27	Swabbed 12/8/75 Acidized 12/22/75
126	2729	3574	130	31	
128	901	1908	170	31	
130	570	1436	165	31	
TOTAL	12170	20654			
201	3131	4198	180	31	
203	676	1487	205	31	Acidized 12/23/75
205	899	1955	205	31	
211	2142	3103	205	31	
223-226	2741	3388	205	31	
215	870	1783	210	31	
221	1435	2705	210	31	
223	2546	3133	195	31	
225	1380	2403	210	31	
TOTAL	15720	*24155			

* NOTE - Last month Cum. Inj. for Hegberg should be 8435 barrels instead of 8453 barrels.

EL DORADO MP PRODUCTION

	207		209		217		219		112		114		122		124		
Date	O	W	O	W	O	W	O	W	O	W	O	W	O	W	O	W	Prod. H_2O
12/3	9	60	Tr	140	2	127	Tr	150	2	115	7	50	2	115	Tr	150	
12/5	9	55	Tr	110	2	125	2	150	2	120	7	40	2	80	Tr	140	
12/8									2	130	7	45	2	80			
12/11	10	50	Tr	155	2	120	2	125	2	130	7	45	2	80	Tr	140	
12/12	3	72	Tr	155	2	120	2	125	2	130	7	45	2	80	1	174	
12/13	3	72	Tr	155	2	120	2	125	2	130	7	27	2	80	1	174	
12/14							4	145	2	137							
12/15			1	112									2	71			
12/16	9	55	Tr	110	2	125	2	150	2	130	7	27	2	80	4	169	715
12/17	9	55	Tr	110	2	125	2	150	2	130	7	27	2	80	4	169	767
12/18	9	55	Tr	110	2	97	2	150	2	130	4	37	2	80	4	169	701
12/19	9	55	Tr	110	2	97	3	137	2	125	4	37	2	80	4	169	764
12/20	Down		Tr	110	2	125	2	150	2	125	4	37	2	80	4	169	634
12/21	Down		3	108											6	156	580
12/22							4	140			5	46					628
12/23	9	55	3	108	2	125	4	140	2	125	5	46	2	80	6	156	647
12/24	9	55	3	108	2	125	4	140	2	125	5	46	2	80	6	156	682
12/25	9	55	3	108	2	125	4	140	2	138	5	46	2	80	6	156	931
12/26	9	55	2	114	2	125	4	140	2	138	5	46	2	80	6	160	936
12/27																	752
12/28																	938
12/29																	878
12/30	9	55	2	114	2	125	4	140	2	138	5	46	2	80	6	156	
12/31	9	55	2	114	2	125	4	140	2	138	5	46	2	80	6	156	926

RESEARCH SUPPORT

Chemical Selection and Support

Mobility Tests. An experiment using Chesney MP-130 core (2.46 cm diameter by 7.3 cm long) joined together with five Berea sandstone cores has been conducted at 3.4 ft/day frontal velocity to determine the total mobilities of the oil-water bank, the micellar solution, and the polymer solution. A micellar slug with the Shell formulation (several pore volumes) was injected in the core followed by a Kelzan F polymer solution. Both the micellar and polymer solutions were filtered with a 1.2 μ filter in line. The total mobilities were determined. Parameters and data used in the total mobility calculations were:

1. Oil-water bank

   $Q = 5$ ml/hr $= 0.00139$ ml/sec

   $\Delta P = 0.0272$ atm

   $A = 4.761$ cm^2

   $L = 3.25$ cm

   Therefore, the total mobility of the oil-water bank,

   $$\left(\frac{K}{\mu}\right)_{ob} = \frac{QL}{A\Delta P} = 0.0349 \text{ darcy/cp}$$

2. Micellar solution

   The viscosity of the solution filtered with a 1.2 μ filter in line was 22.2 cp at a shear rate of 22.50 sec-1.

   $Q = 5$ ml/hr $= 0.00139$ ml/sec

   $\Delta P = 0.1680$ atm

   Therefore, the mobility of the chemical solution.

   $$\left(\frac{K}{\mu}\right)_m = \frac{QL}{A\Delta P} = 0.0139 \text{ darcy/cp}$$

   The viscosity of the produced chemical solution after the pressure across the core stabilized was 22.8 cp at a shear rate of 22.50 sec^{-1}.

3. Polymer Solution

The viscosity of the polymer solution filtered with a 1.2 μ filter in line was 31.4 cp at a shear rate of 22.50 sec^{-1}

$Q = 5ml/hr = 0.0139$ ml/sec

$\Delta P = 0.0952$ atm

Therefore, the mobility of the polymer solution,

$$\frac{(K)}{(\mu)} = \frac{QL}{A\Delta P} = 0.01 \text{ darcy/cp}$$

The viscosity of the produced polymer solution after the pressure across the core stabilized was 29.7 cp at a shear rate of 22.50 sec^{-1}.

Surfactant and Polymer Work. Samples of Witco sulfonates to be used in Union process and Nalco new polymer (improved quality) were received. Testing of these chemicals is under way.

The loss of surfactant to Admire 650-foot crushed rock and to a one-inch diameter by three-inch long core plug of 650-foot Sand were determined for the surfactant system described in Shell's preliminary design (other systems closely related to Shell's were also studied). A flow test resulted in a loss of 0.1 milliequivalents of active surfactant per 100 grams of Admire 650-foot rock. This loss is equivalent to a little more than one pound of active surfactant per barrel of pore volume. The loss of surfactant to samples of crushed Admire 650-foot rock showed a large variation, ranging from a loss of 0.03 to 0.37 milliequivalents of active surfactant per 100 grams of crushed Admire rock. The differences may be due at least in part to differences in the clay content of each sample.

Adsorption of Shell's formulation of surfactant was run on core from MP-215 (654 ft). The 2.54 cm by 7.3 cm plug weighed 68.265 g and had a pore volume of 8.66 ml. The adsorption was found to be time dependent. The initial

adsorption, that is, during flow, was 0.11 meq/100 g. After being shut in it was observed that an additional 0.048 meq/100 g of surfactant was adsorbed. A flow test on another plug is currently in progress. An adsorption number of the Union formulation will be obtained next.

Shell sulfonate blend was prepared according to Shell's recommendations. Viscosity of the blend agrees with the value reported by Shell.

A meeting withShell was held the Cities' Tulsa Laboratory on December 4, 1975, to discuss the field injection program, chemical slug design, and process evaluation.

Injectivity and Chemical Sensistivity Tests. Cores from both wells MP-215 and MP-106 were used to test the sensitivity of El Dorado cores to various chemical solutions. The results are given in the table below. These results indicate that (1) 2.0 percent NaCl, 1.0 percent NaCl, and El Dorado lake water did not seem to affect the permeability significantly; (2) the Union chemical preflush caused a great reduction of permeability (Test #3); and (3) if soluble oil was used prior to the injection of Union preflush solution, then the core seemed to be insensitive to all of the solutions lised in this table (Test #4).

Test #4 and the previous injectivity test performed in the field (see the first annual project report, July, 1975) seem to show that it would be desirable to use a small quantity of soluble oil to treat all the injection wells prior to the injection of Union preflush. Soluble oil can probably also be used to replace xylene in acidizing the low injectivity wells.

INJECTIVITY TEST OF EL DORADO CORES

Test No. / Core From Well	Permeability, md 1 MP-215	2 MP-106	3 MP-106	4 MP-106
Chesney 195 water	33	193	294	315
50/50, Chesney 195/Lake Water		152		
2 Percent NaCl	33	159		
1 Percent NaCl	21	159		
Lake Water	29	131	255	304
Chesney 195 Water		147		
50/50, Chesney 195/Lake Water		136		
Shell Preflood		136		
Union Preflush			20	
Soluble Oil			201	2028 (?)
Lake Water				278
Union Preflush			44	431
Lake Water				311

One test was conducted to investigate the injectivity of Kelzan Biopolymer in El Dorado cores. A 1400 ppm biopolymer solution was prepared in a mixture of 1.0 weight percent Chesney produced water and 99 percent filtered (lake) water. The solution was filtered using a 1.2 μ millipore filter before injection. Initially, the core was saturated and flooded with Chesney brine. Permeability to water was low (18.6 md). Several pore volumes of Shell sulfonate blend were injected to clean the core before polymer injection. Approximately ten pore volumes of the polymer were injected during the test, never reaching a steady-state condition. Injection face pressure continued to rise indicating severe plugging as a possible problem. A new procedure for preparing the biopolymer was received from Shell and will be tested for injectivity in the near future.

Oil Displacement Tests. The result from an oil displacement test using the Union formulation with a new experimental procedure showed that residual oil saturation was reduced to 15 percent in short (two-inch diameter by nine-inch long) stacked El Dorado cores. If one makes a reasonable extrapolation using previous results of ten-inch cores compared to four-foot cores (both Berea and El Dorado type), a residual oil saturation of approximately 5 percent or even lower should be expected in the field in the swept region.

General Chemical Support Work. The cause(s) and solution(s) for the quite low injectivity rates at El Dorado were studied during December. Assistance was rendered in collecting several water samples in the field. The barium sulfate scale treatment of wells MP-114 and MP-207 received additional study. A large number of analyses of dissolved and suspended solids in water were done as part of these investigations.

The Company files of old El Dorado well records contain comments on water analyses. These files were searched for the sulfate content of the overlying water sands, but no good data were found. (See also the section "Pressure Transient Tests and Well Stimulations".)

A new set of charts was prepared for use at El Dorado to determine the proper quantity of saturated brine to be used in both the Chesney and Hegberg patterns. A set of directions for doing the Mohr method of chloride analysis was verbally communicated to the Project Engineer on December 23.

Recommendations were made for field injection water quality control and analysis. Time was spent at the project site in El Dorado running water quality tests. In addition, some time was spent organizing the field laboratory.

Coring and Core Analyses

Steady-state relative permeability data have now been measured on two native-state samples from MP-217. Using El Dorado crude and produced waters, water permeabilities at flood-out were found to be 17-20 percent of the absolute air permeabilities. Additional tests are scheduled to investigate water-oil mobilities.

A paper entitled "Core Analysis Study for the El Dorado Micellar-Polymer Project" has been prepared for presentation at the Society of Petroleum Engineers of AIME Improved Oil Recovery Symposium in Tulsa in March, 1976.

Literature Work

A rough draft of the bibliography for the search of the micellar-polymer flood literature has been completed. A copy of this draft was sent to Ms. Jean Meister of the ERDA Bartlesville Energy Research Center.

Pressure Transient Tests and Well Stimulations

During December, bottom-hole pressure surveys were conducted in all the monitoring wells in the Chesney and Hegberg patterns. These data, coupled with injection rates and pressures, were used to determine if reduced injection rates were caused by pressuring up of the patterns or injection well damage.

Soon after the start of fluid injection in the El Dorado Micellar-Polymer Project, injection pressures increased at an abnormal rate and injection rates declines far below the predicted levels. In an effort to isolate the problem, injection and observation well pressures and rates were measured and analyzed. This information was then compared with background data measured prior to start-up. As a result of this survey, it was clear that the observed reduction in injection rates was not due to pressuring up the pattern area. The results of these tests and analysis were reported in an inter-office letter to the Project Manager from V. W. Rhoades, December 10, 1975.

Union and Shell personnel were both consulted with regard to well treatments. Their confirmations on quantity and type of chemicals used to acidize low injectivity wells were obtained.

A final summary of directional permeability test along with supporting theoretical development is nearing completion. It is anticipated that this memo will also serve as a basis for a paper to be present at the Society of Petroleum Engineers of AIME Improved Oil Recovery Symposium in March, 1976.

Performance Prediction

The superposition-of-line-sources program was used to compute injection and production rates during preflush injection with large positive skin factors on the injection wells. The latter were taken from the results of the pressure tests run after the severe loss in injectivity was observed late in November and early December. Very good agreement between observed and calculated rates was obtained when Kh values of 878 and md-ft for Chesney and 493 md-ft for Hegberg lease were used. These values were taken from a memo by S. C. Swift written earlier in 1975. The observation well pressures were also matched well.

Several modifications that increase the capabilities of the superposition-of-line-source-solutions reservoir simulator were completed.