POLYMER GEL USED TO REDUCE PRODUCED WATER

Aaron Fuhr and Arturo Pena, ConocoPhillips Company
Don Pender, Gel Tec

ABSTRACT

The use of a polymer gel to reduce large volumes of water production in an aquifer-supported oil reservoir will be presented. Water invasion from the underlying aquifer had begun to water out the completion and repeated plug backs and cement squeeze attempts failed to block the water movement into the wellbore. A vertical permeability channel to the upper perforations in the near wellbore region was suspected to be the cause. A polymer gel treatment through the bottom perforations was selected to shut-off or divert the water. The gel (developed by Marathon Oil Co.) reduces the permeability thus creating a “blockage” in the formation channel. The job was successfully performed, and resulted in an 81% decrease in water production with negative impact to oil production.

HISTORY

The well was perforated in the lowest interval on 3/31/2006. This set of perforations produced approximately 400 barrels of water per day, with no oil. Following the initial test, this set of perforations was cement squeezed, and two sets of perforations were added uphole on April 27, 2006. These two sets of perforations made approximately 4 barrels of oil and 370 barrels of water per day. They were subsequently cement squeezed on 5/16/2006. Two more sets of perforations were then added. These perforations produced 13 barrels of oil per day and 346 barrels of water per day. The cement squeeze on the lower sets of perforations was tested in November 2006. All three previously squeezed sets of perforations failed to hold during the test. At this time, an ESP was run in the well while options were evaluated, and the well subsequently produced 1400+ barrels of water, with no oil. As a final effort to isolate the produced water, a CIBP was set above the top squeezed producing perforation. Subsequent to this operation the well produced 44 barrels of oil per day and 1400+ barrels of water with very little gas. **Figure 1**.

POLYMER GEL TREATMENT

Reason for Treatment: The reason for treating the well was to reduce permeability in the lower Glorieta intervals that were producing a large volume of water and very little oil. Cement squeezes and mechanical isolation had been attempted in these zones but the vertical communication between these intervals was not altered. The polymer gel would be used for in depth reservoir diversion of the water, as opposed to a wellbore or near-wellbore procedure.

Chemicals Used: The chrome-carboxylate/acrylamide-polymer (Cr^{+3}) gel system, used successfully in several injectors, was developed by Marathon Oil Company. A chromium acetate was used to crosslink to gel low-concentration polyacrylamide polymers. This gel provides a high residual resistance factor to water when injected into the formation. The gel system is a clear fluid that is pumped as a complete solution and is easily pumped. Also, the Cr^{+3} does not pose a serious problem to safety and the environment.

Treatment Procedure: The gel treatment was performed on December 20-21, 2007. The treatment was pumped under a packer (6086’) that was set below the upper perforations. **Figure 2**. A 1,003 barrel treatment using 1705 lbs of polymer was pumped into the lower zone while water was being pumped down the tubing/casing annulus to protect the upper perforations.

The first stage consisted of 400 barrels of 3500 ppm polymer gel. There was no surface pressure response. The second stage was 278 barrels of 4500 ppm polymer gel. Again, no surface pressure response was observed. The third stage was 199 barrels of 5500 ppm polymer gel. Approximately 200 barrels of polymer gel was pumped when the well finally had a surface pressure reading of 213 psi. The final stage consisted of 126 barrels and 7,000 ppm of polymer gel with a final pressure of 1032 psi. The tubing was then flushed with water to displace remaining gel from the tubing and wellbore area. At the same time, the tubing /casing water injection was terminated. **Table 1**.

Quality Control: Samples of each gel stage were collected and heated at reservoir temperature to confirm gelation. The samples were graded according to Marathon's Bottle Test Gel Strength Coding System. These samples were retained and made available.

CASE HISTORY

The well was swabbed after the polymer gel treatment. The initial swab runs (8) recovered 0 BO and 30 BW with some samples of polymer gel. The fluid level declined from 5000' to 5400'. Subsequent swab runs (18) produced only 46 BW with traces of gel and a fluid level of 6000'. It was determined that further swabbing would produce little to no fluid. The swabbing was suspended and the well was placed on rod pump.

The well pumped off (intake @ 6099') in a few strokes indicating no fluid entry. The decision was made to acidize the upper perforations in an attempt to restore production. A retrievable bridge plug was set @ 6080' and the well was acidized with 5000 gallons of 15% HCL using 1.3 sp.gr. ball sealers. The acid was pumped at a matrix rate of 3.3 bpm with a maximum pressure of 2800 psi and an ISIP of 629 psi. The well was swabbed but recovered only 10 bbls of fluid. The following day, the initial swabs showed an increase in oil percentage and the well was placed on rod pump. The post stimulation well tests showed an increase in oil with much less water**. Figure 1**.

ECONOMICS

When the well was on ESP, it produced about 44 bopd, 1275 bwpd and very little gas. After the polymer gel/acid treatment and the installation of rod pumping equipment, the well initially produced about 91 bopd, 241 bwpd and 5 mcfpd. It is currently producing 35 bopd, 235 bwpd and 30 mcfpd**. Figure 3**. However, the produced water has been decreased to about 81%. The oil is now steady at 35 bopd with an increase in gas of 30 mcfpd. Although there was a slight reduction of oil from 44-35 bopd, the well is now pumping every day as opposed to only pumping intermittently and/or other wells in the field had to be shut-in due to water handling problems at the battery. In addition, the downsizing from ESP to rod pumping has resulted in an 88% reduction of electrical consumption (~$5600/month).

CONCLUSION

- The polymer gel system can be used to effectively reduce produced water.
- Precautions should be made to avoid gel squeezing the oil producing interval.
- The acid treatment should be done at a matrix rate to avoid fracturing into the water channels.

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NOMENCLATURE

ESP – electrical submersible pump
CIBP – cast iron bridge plug
PPM – parts per million
BO – barrels of oil
BW – barrels of water
MCF – million cubic feet

Table 1
Actual Treatment Report and Injection Time Log

Actual Treatment

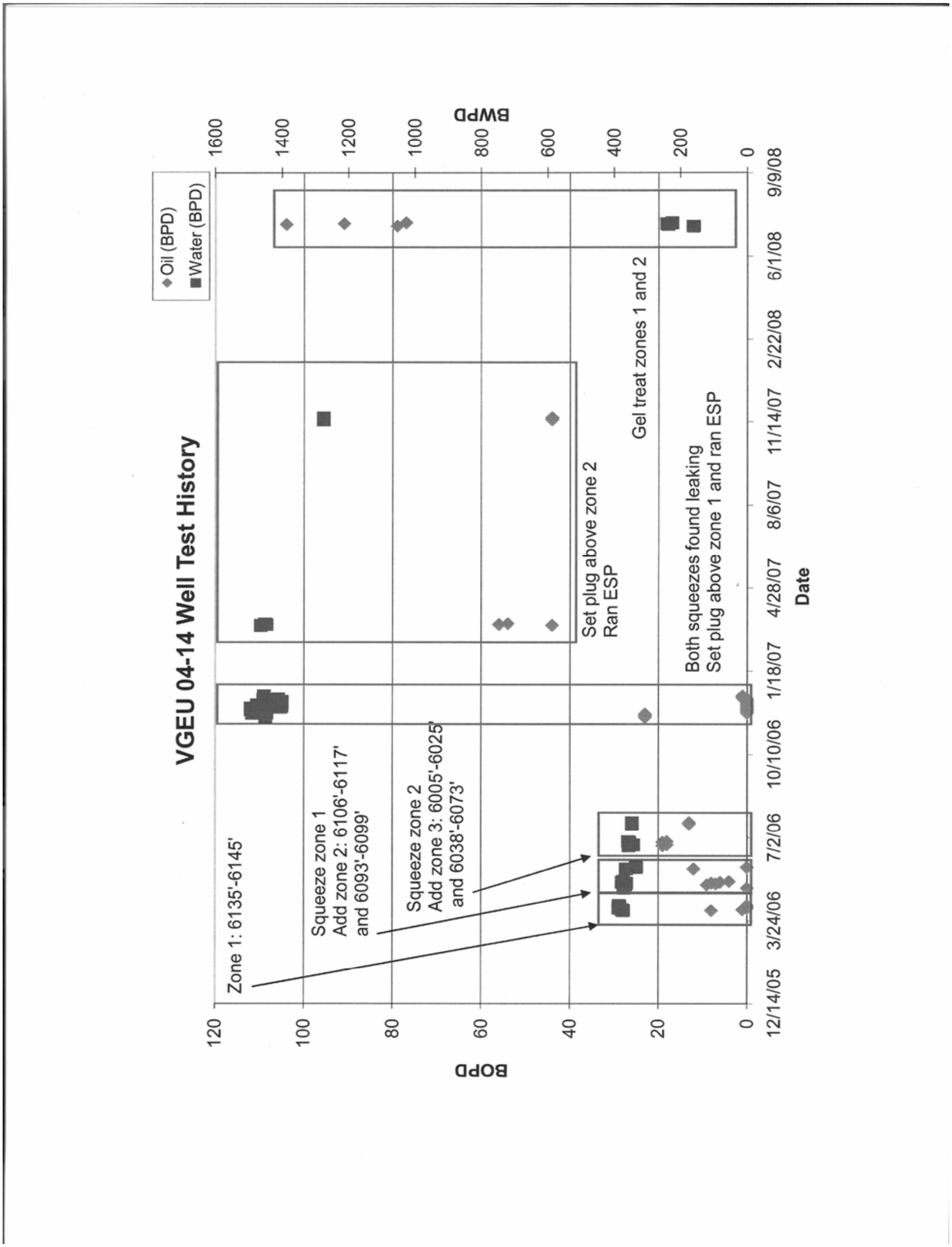
Stage	Volume (bbls)	Polymer (ppm)	Polymer (lbA)
H_2O Pre-flush – tubing	50	0	0
H_2O Pre-flush – casing	30	0	0
Gel #1	400	3500	519
Gel #2	278	4500	456
Gel #3	199	5500	405
Gel #4	126	7000	325
Water Flush – Tubing	40		
Water Flush – Casing	30		

Injection Log

Date	Time	Description	Cum. Vol. (bbls)	Inj. Rate (BPD)	Pressure (psi)
12-19-07	2000	Arrive on location			
12-20-07	0955	Safety Meeting/MIRU			
	1203	Pressure test – TIW valve not holding			2000
	1207	Start Preflush down tubing	0	750	0
	1321	SD, switch to backside	50	973	0
	1408	Stop and prep gel	80	960	0
	1430	Start Gel #1 - 3,500-ppm	80	1400	0

	1700	Pump 10 bbls down backside	146	1392	1
	1711	Switch to gel down tubing	156	1309	1
	1900	Pump 10 bbls down backside	264	1440	2
	1910	Switch to gel down tubing	274	1440	20
	2100	Pump 10 bbls down backside	381	1392	1
	2111	Switch to gel down tubing	391	1309	13
	2150	Start Gel #2 – 4,500-ppm	430	1440	1
	2300	Pump 10 bbls down backside	497	1378	2
	2311	Switch to gel down tubing	507	1309	27
12-21-07	0100	Pump 10 bbls down backside	613	1416	2
	0112	Switch to gel down tubing	623	1200	19
	0300	Pump 10 bbls down backside	728	1392	2
	0311	Switch to gel down tubing	738	1309	35
		Start Gel #3 – 5,500-ppm			
	0500	Pump 10 bbls down backside	843	1368	0
	0512	Switch to gel down tubing	853	1200	91
	0700	Pump 10 bbls down backside	935	1163	517
	0715	Switch to gel down tubing	945	960	419
	0734	Start Gel #4 – 7,000-ppm	957	909	409
	0841	SD, Monitor Pressure	997	843	603
	0900	Pump 10 bbls down backside	997	900	0
	0917	Switch to gel down tubing	1007	847	323
	0944	SD, Monitor Pressure	1022	800	682

Date	Time	Description	Cum. Vol. (bbls)	Inj. Rate (BPD)	Pressure (psi)
	1007	Restart gel	1022	800	0
	1100	Pump 10 bbls down backside	1056	924	930
	1117	Switch to gel down tubing	1066	847	990
	1228	Start Water Flush down tubing	1103	750	1032
	1353	Start Water Flush down casing	1143	678	1190
	1456	End Water Flush	1173	686	1094
		ISIP			1025
		1-min			906
		5-min			682
		10-min			451
		15-min			302
		20-min			213
		25-min			145
		30-min			99



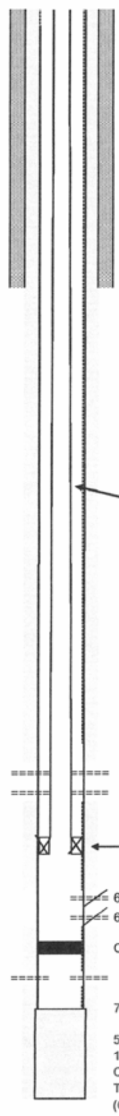
VGEU 04-14 Well Test History
Oil (BPD)
Water (BPD)
BOPD
BWPD
Date
Zone 1: 6135'-6145'
Squeeze zone 1
Add zone 2: 6106'-6117'
and 6093'-6099'
Squeeze zone 2
Add zone 3: 6005'-6025'
and 6038'-6073'
Both squeezes found leaking
Set plug above zone 1 and ran ESP
Set plug above zone 2
Ran ESP
Gel treat zones 1 and 2
12/14/05
3/24/06
7/2/06
10/10/06
1/18/07
4/28/07
8/6/07
11/14/07
2/22/08
6/1/08
9/9/08
0
20
40
60
80
100
120
200
400
600
800
1000
1200
1400
1600

Figure 1

CONOCOPHILLIPS
WELLBORE DIAGRAM
VACUUM GLORIETA EAST UNIT #04-14

Date: **1/12/09**

Lease & Well No. :	**Vacuum Glorieta East Unit #04-14**
Legal Description :	*308' FNL & 990' FWL, Sec. 33, T17S, R35E*
County :	Lea State : New Mexico
Field :	Vacuum Glorieta East Unit
Date Spudded :	March 2, 2006
API Number :	30-025-37432
Status:	Active Producer



Stimulation Histort

Interval	Date	Type	Gals	Lbs. Sand	Max Press	ISIP	Avg Rate
6135-6145'	3/30/06	20% HCL	2500	-	6000	1000	7 to 0
			(40 ballsealers as diverter)				
6093-6117'	4/28/06	20% HCL	4000	-	5900	0	1/4 to 8
			(70 ballsealers as diverter)				
6005-6073'	5/20/06	20% HCL	10000	-	0	0	0 to 8
			(200 ballselers as diverter)				
6093'-6117'	12/20/07	Gel Trt	45906	1705	1190	1025	

Figure 2

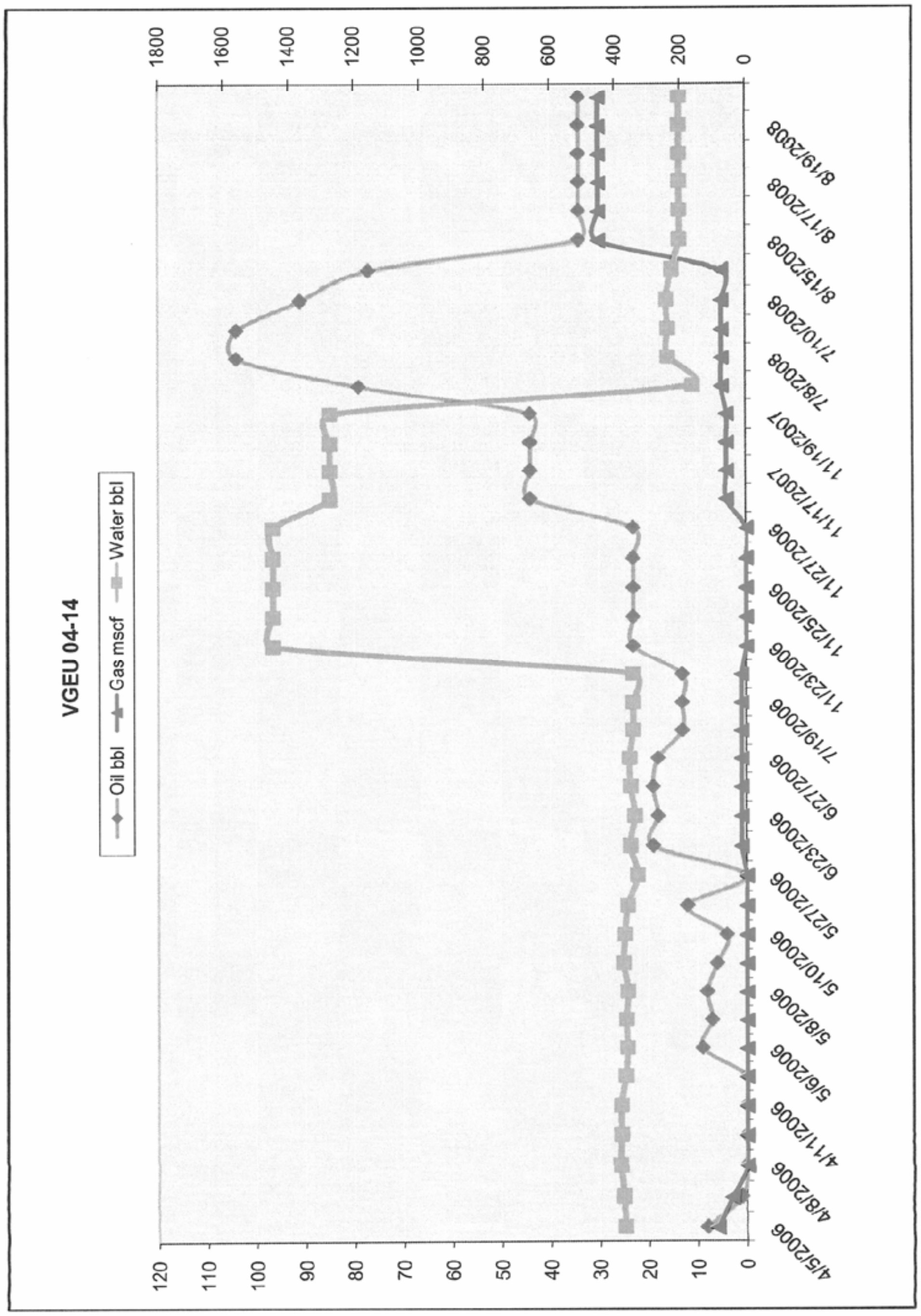

VGEU 04-14
Oil bbl
Gas mscf
Water bbl
4/5/2006
4/8/2006
4/11/2006
5/6/2006
5/8/2006
5/10/2006
5/27/2006
6/23/2006
6/27/2006
7/19/2006
11/23/2006
11/25/2006
11/27/2006
11/17/2007
11/19/2007
7/8/2008
7/10/2008
8/15/2008
8/17/2008
8/19/2008

Figure 3