FIELD EVALUATION OF GELLED ACID FOR CARBONATE FORMATIONS

by D. C. Church, J. L. Quisenberry and K. B. Fox
Dowell Division of Dow Chemical U.S.A.

ABSTRACT

A new gelled acid was evaluated in the West Texas, Southeast New Mexico and Oklahoma areas. The purpose of this evaluation was to determine how successful a gelled acid, prepared from xanthan polymer, would be in the following formations: Ellenburger, Blinebry, San Andres, Clearfork, Canyon Lime, Strawn Lime, Grayburg, Devonian, Drinkard Dolomite, Viola and Chester. Treatment depths vary from 4,000 to 22,000 ft. Treatment temperatures vary from 70° to 310°F. Treatments were performed on both oil and gas wells. The age of the wells stimulated varies from new to 30 yr old. The concentration of gelled acid remained constant at 15% HCl. The concentration of gelling agent remained constant at 60 lb/1000 gal. The size of the treatments varied from 5,000 to 80,000 gal of gelled acid. More than 20 treatments are summarized.

Several types of acidizing techniques were employed using gelled acid. These treatments vary from one to nine stages with and without diverting agents and with and without leakoff control additives. These treatments vary from 2 to 15 BPM. Some of these treatments contained 20/40 Sand, N_2 and/or radioactive tracers.

Production figures for the wells treated are discussed, as well as pertinent related information.

INTRODUCTION

It has been reported in previous literature that to obtain optimum results from a fracture-acidizing treatment, live acid must penetrate as far into the reservoir as possible.[1] Treatment procedures currently being employed attempt to accomplish this through one, or a combination, of the following methods.

1. Acid retardation.
2. Increased fracture width to decrease the area-volume ratio.
3. Improved leakoff control.
4. Increased acid strength.

The "Frac Pad and Acid Technique"[2] and the use of alternate stages of a viscous nonreactive pad fluid and acid[3] were developed to attain deeper penetration.

These methods incorporate nonreactive gelled pad fluids to control acid leakoff rates and to reduce the area of formation exposed to a given volume of acid by increasing the width of the fracture. Ideally, the same advantages could be realized by thickening the acid itself. This could provide the added benefit of reducing or eliminating the nonreactive, unproductive gelled pad fluid. However, economical acid gelling agents which would not degrade in typical acid concentrations either at ambient temperatures or, more importantly, under downhole treating conditions of elevated temperatures and acid spending were not previously available.

Recently, a gelled acid, using a xanthan polymer as the basic gelling agent, was introduced. This system develops a relatively high viscosity and is stable under most conditions. This thickener, tested in numerous field applications and discussed in this paper, has demonstrated considerable overall potential for use as an acid gelling agent.[4]

CHARACTERISTICS AND ADVANTAGES

Increasing the viscosity of a fluid, through the addition of gelling agents, reduces leakoff into the matrix of the rock and any secondary porosity such as hairline fractures, either natural or induced. The same is true for a gelled acid. By controlling leakoff during acidizing, fluid efficiency is improved and more acid remains in the primary fracture, allowing for deeper penetration. The addition of 60 lb of acid thickener per 1000 gal of 15 per cent HCl produces a fluid with a viscosity of 25 cp (511 sec^{-1}) at 100°F. The gelled acid retains viscosity during spending and exhibits this stability up to 220°F,[4] thus maintaining its fluid efficiency.

Acid which is gelled will have a reduced reaction rate. Fifteen per cent HCl gelled with 60 lb of xanthan polymer per 1000 gal of acid yields a 3.6-fold increase in spending time. This is a 69 per cent reduction in reaction rate when compared with ungelled acid.[4] There are two mechanisms at work to accomplish the retardation in a gelled acid system. First, a viscous fluid creates a wider fracture, thus decreasing the area-volume ratio and reducing the mass-transfer rate to the fracture wall. Secondly, due to this increased fracture width, the gelled acid will remain in laminar flow at higher pump rates.[5] This permits live acid to travel a greater distance into the formation than if it were in a turbulent flow regime.

Since the gelled acid has stable viscosity and does not break upon spending, the fluid properties noted above are maintained throughout the entire treatment. An added benefit with this stable viscosity has been improved cleanup of insoluble silts and fines released by the acid. The acid retains enough viscosity to suspend and return these fines following the treatment. It is not so viscous as to impose substantially longer-than-normal cleanup times. This contributes to improved long-term production results by removing insoluble solids which, if left behind in the formation, could reduce fracture flow capacity as they migrate toward the wellbore.

In summary, the polymer tested imparts a stable viscosity to hydrochloric acid concentrations up to 15 per cent. This retards the reaction rate and controls acid fluid loss for increased penetration, improved etch patterns and fracture conductivity. This retarded reaction rate and improved fluid-loss control allow the use of lower acid concentrations and less total fluid volumes to achieve maximum penetration of live acid. Additional viscous pad fluids are not required although they may be used to control acid fluid loss since the acid is a stable, viscous, reactive fluid. Therefore, many times less load fluid needs to be recovered following the treatment.

FIELD EVALUATION

Several types of acidizing techniques were employed using 15 per cent HCl gelled with 60 lb of polymer per 1000 gal of acid. These treatments varied from one to nine stages. In some instances, diverting agents and solid leakoff control additives (i.e., 100-mesh sand and 100-mesh salt) were used between stages. Injection rates varied from 2 to 15 BPM, and the volume of treatments ranged from 5,000 to 80,000 gal of gelled acid. Nitrogen was used in some treatments to aid in accelerated fluid recovery. No problems involving mixing, gel stability or pumping were encountered.

The gelling agent proved to be compatible with most acidizing additives commonly used in conventional ungelled acid systems. There were no difficulties experienced in cleanup following the treatment, either from excessive viscosity or emulsions. In fact, due to dilution with connate waters and/or other fluids pumped with the treatment, the viscosities were less than expected, the average being 15 cp (511 sec^{-1}). Large amounts of undissolved solids were recovered from some wells. X-ray diffraction analysis indicated the composition of these fines was primarily halite, anhydrite, gypsum and quartz. It should be noted that an emulsion study between the gelled acid and crude oil should be conducted prior to treatment. This is done to determine which demulsifier will be required to prevent the formation of an emulsion since undissolved solids and fines suspended in the spent acid will tend to stabilize emulsions.

Since the gelled acid is stable for extended periods at ambient temperatures (Fig. 1), much of the gelled acid used in the case histories listed was gelled up to 24 hr prior to the treatment. There was little or no significant loss of viscosity during this period, and the gelling agent remained in solution without signs of separation.

In most instances, the productivity/injectivity of the wells treated was increased beyond expectations. Furthermore, resulting stimulation surpassed results obtained using conventional treatment techniques in the same area.

Case Histories

Case I

Ward County, Texas
Ellenburger Formation, 22,154 to 22,487 ft
BHST: 310°F

Treatment

1. 10,000 gal of gelled water for cool-down.
2. 2,000 gal of 15% gelled HCl.
3. 2,000 gal of gelled water overflush.
4. Ball sealers for diversion.
5. Repeat Steps 2 through 4, six times.
6. 2,000 gal of 15% gelled HCl.
7. 1,000 gal of gelled water.
8. Flush to perforations with water.

300 SCF of nitrogen per bbl of fluid after first 6,000 gal of gelled acid.

Results

Operator was able to light a flare two hours after treatment. Well was producing 5.2 MMCFD at 2600 psi.

Case II

Ward County, Texas
Fusselman Formation, 19,938 to 19,977 ft
BHST: 295°F

Treatment

1. 10,000 gal of gelled water for cool-down.
2. 6,000 gal of 15% gelled HCl.
3. 5,000 gal of gelled water overflush.
4. 6,000 gal of 15% gelled HCl.
5. 5,000 gal of gelled water overflush and flush.

500 SCF of nitrogen per bbl in all fluids.

Results

Well cleaned up and was producing 7.4 MMCFD at 3300 psi.

Case III

Hockley County, Texas
San Andres Formation, 5000 ft
BHST: 115°F

Treatment

1. 1500 gal of 15% gelled HCl containing 1 lb/gal 100-mesh sand.
2. 2000 gal of 15% gelled HCl containing 2 lb/gal 100-mesh sand.
3. 1000 gal of 15% gelled HCl.
4. 2000 gal of gelled water overflush.
5. 500 gal of gelled water containing solid blocking materials.
6. Repeat Steps 1 through 4.
7. Flush with gelled water.

Results

Thirty days after stimulation, this well was producing 65 BOPD and 376 BWPD compared to the 21 BOPD and 14 BWPD prior to the treatment. Oil production after 60 days had increased to 68 BOPD. The usual result in this area following acidizing with nongelled 15 per cent HCl is 40 BOPD.

Case IV

Gaines County, Texas
Clearfork Formation, 6,465 ft
BHST: 130°F

Treatment

82,500 gal of gelled pad (30% lease oil).
82,500 gal of gelled 15% HCl.

The treatment was performed in nine stages. A bridge plug and packer were used to isolate the perforations for each stage. The injection rate varied from 9 to 15 BPM.

Results

This well cleaned up quickly and gave an initial production response of 225 BOPD. After 30 days, the well was still producing 170 BOPD. Two offset wells, treated with identical volumes of gelled pad and 20 per cent HCl, had production rates of 100 and 116 BOPD after 30 days.

Case V

Lea County, New Mexico
Drinkard Formation
BHST: 90°F

Treatment

16,000 gal of gelled water pad.
26,000 gal of gelled 15% HCl.
7,500 gal of gelled water flush.
24,000 lb of 100-mesh salt.

This treatment was divided into four equal stages, with 400 lb of diverting agents dropped between stages. The well treated at 1850 psi with an average injection rate of 6 BPM.

Results

This treatment represented a restimulation of a producing formation. Production prior to the gelled 15 per cent HCl treatment was 6 BOPD, 0 BWPD and 200 MCFD of gas. Twelve days after stimulation, the production increased to 25 BOPD, 10 BWPD and 705 MCFD of gas.

Case VI

Love County, Oklahoma
Viola Formation
BHST: 150°F

Treatment

10,000 gal of gelled 15% HCl.
5,000 gal of gelled water pads.

This well was treated in 10 stages using ball sealers for diversion.

Results

Wells were swabbing 8 to 10 bbl of oil per hr prior to treatment. After the acid job, wells were swabbing 50 to 80 bbl of oil per hr. Wells in this area usually require fracture treatments following the acid job. This well was produced for six months before fracturing was necessary.

Further results are presented in Tables 1 and 2.

CONCLUSIONS

1. Gelled acid provides deep penetration of live acid and increased fracture flow capacity by controlling leakoff.

2. Viscosifying acid retards the reaction rate, thus allowing deeper live acid penetration.

3. Acid gelled with the xanthan polymer does not break upon spending.

4. Gelled acid provides more effective use of given acid volumes.

5. Gelled acid suspends insoluble silts and fines for improved cleanup and increased fracture conductivity.

6. In many cases, gelling the acid reduces the treatment volumes necessary to obtain maximum penetration of live acid.

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TABLE 1—OIL AND GAS WELL FIELD RESULTS 15% GELLED ACID

State	County	Formation	Depth	Treatment	Production BWO*	Production AWO**
Texas	Hockley	San Andres	4,800	10,200 gal gelled 15% HCl 7,000 gal gelled pad	25 BOPD 34 BWPD	42 BOPD 48 BWPD
Texas	Hockley	San Andres	4,753	10,200 gal gelled 15% HCl 7,000 gal gelled pad	3 BOPD 300 BWPD	15 BOPD 440 BWPD
Texas	Hockley	San Andres	4,758	6,000 gal gelled 15% HCl 11,000 gal gelled pad	41 BOPD 33 BWPD	68 BOPD 44 BWPD
Texas	Hockley	San Andres	5,032	10,200 gal gelled 15% HCl 7,000 gal gelled pad	9 BOPD 8 BWPD	19 BOPD 32 BWPD
Texas	Hockley	San Andres	4,728	5,500 gal gelled 15% HCl 5,000 gal gelled pad	37 BOPD 100 BWPD	53 BOPD 413 BWPD
Texas	Andrews	Devonian	8,500	7,500 gal gelled 15% HCl	20 BOPD 333 BWPD	98 BOPD 697 BWPD
Texas	Ector	Strawn Lime	7,536	30,000 gal gelled 15% HCl 15,000 gal gelled pad	65 BOPD 25 BWPD	125 BOPD 50 BWPD
Texas	Pecos	Atoka	22,176	20,000 gal gelled 15% HCl 40,000 gal gelled pad	New	10.2 MMCFD
New Mexico	Lea	Drinkard	6,810	26,000 gal gelled 15% HCl 16,000 gal gelled pad 24,000 lb 100-mesh salt	New	52 BOPD 10 BWPD 3.5 MMCFD
New Mexico	Lea	Drinkard	6,818	15,000 gal gelled 15% HCl 12,000 gal gelled pad 12,000 lb 100-mesh salt	New	35 BOPD 100 BWPD 250 MCFD
New Mexico	Lea	Drinkard	6,818	9,000 gal gelled 15% HCl 9,000 gal gelled pad 15,000 lb 100-mesh salt	New	25 BOPD 80 BWPD 250 MCFD
New Mexico	Lea	Drinkard	6,800	19,500 gal gelled 15% HCl 12,000 gal gelled pad 18,000 lb 100-mesh salt	New	65 BOPD 0 BWPD 4 MMCFD
Texas	Yoakum	San Andres	5,050	9,000 gal gelled 15% HCl 12,000 gal gelled pad 13,500 lb 100-mesh salt	48 BOPD 384 BWPD	60 BOPD 476 BWPD
Texas	Yoakum	San Andres	5,000	9,000 gal gelled 15% HCl 12,000 gal gelled pad 13,500 lb 100-mesh salt	12 BOPD 300 BWPD	84 BOPD 707 BWPD
New Mexico	Roosevelt	San Andres	4,033	150 gal 20% HCl 13,000 gal gelled 15% HCl	New	48 BOPD
New Mexico	Lea	Bone Springs	9,260	15,000 gal gelled 15% HCl 10,000 gal gelled pad	New	75 BOPD 265 BWPD Flowing
Texas	Pecos	Strawn Lime	16,000	40,000 gal gelled 15% HCl 20,000 gal gelled pad	30 BOPD 18 BWPD	70 BOPD 15 BWPD
Oklahoma	Harper	Chester	7,200	7,000 gal 15% gelled HCl 3,000 gal gelled pad	5 BOPD 1.5 MMCFD	10 BOPD 2.8 MMCFD
Oklahoma	Woodward	Chester	8,400	40,000 gal 15% gelled HCl 20,000 gal gelled pad	1.6 MMCFD	6.8 MMCFD
Oklahoma	Dewey	Chester	6,200	20,000 gal 15% gelled HCl	50 MCFD Show of oil	45 BOPD 250 MCFD

*Before Workover
**After Workover

TABLE 2—INJECTION WELL FIELD RESULTS 15% GELLED ACID

State	County	Formation	Depth	Treatment	Injection BWO*	Injection AWO**
Texas	Hockley	San Andres	4,748	6,000 gal 15% gelled acid 11,000 gal gelled pad	255 BWPD @ 1,040 psi	395 BWPD @ 1,040 psi
Texas	Hockley	San Andres	4,820	6,000 gal 15% gelled acid 7,500 gal gelled pad	50 BWPD @ 1,000 psi	459 BWPD @ 1,000 psi
Texas	Hockley	Clearfork	5,808	5,000 gal 15% gelled acid 5,250 gal gelled pad	80 BWPD @ 1,000 psi	175 BWPD @ 1,110 psi

*Before Workover
**After Workover

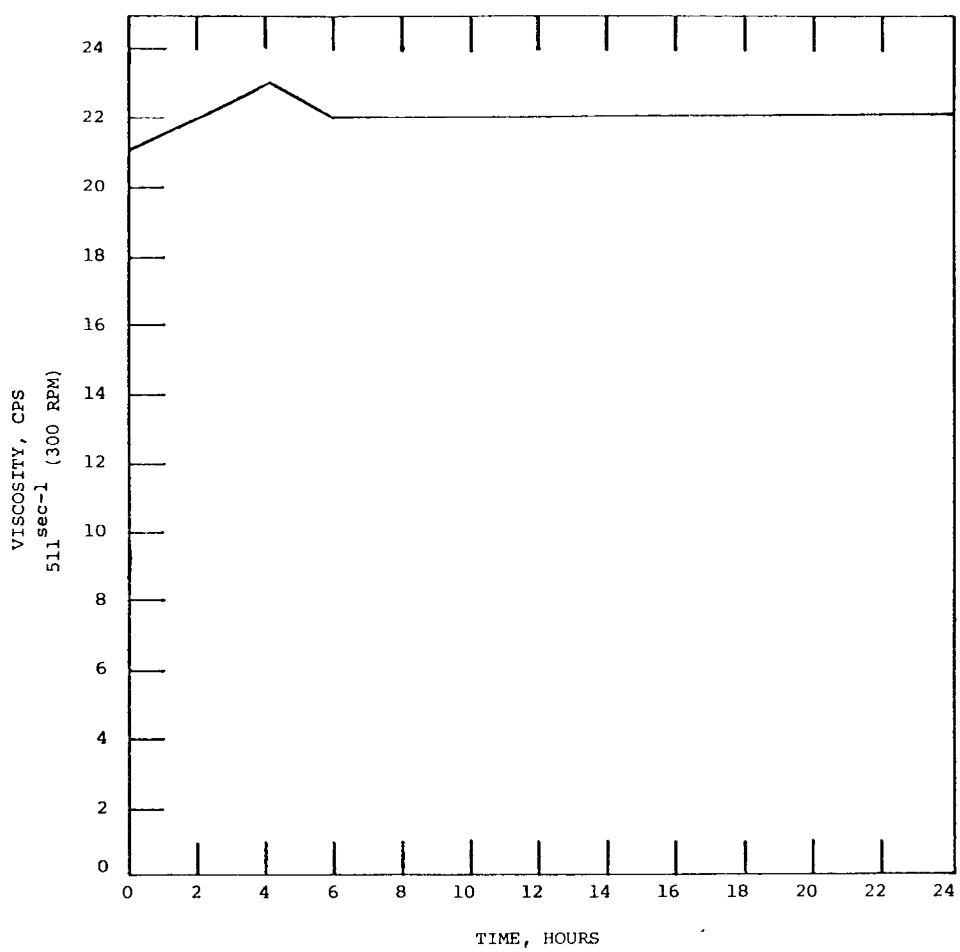

FIGURE 1—VISCOSITY LOSS VERSUS TIME FOR 15% HCL, GELLED WITH 60 LBS. XANTHAN POLYMER PER 1000 GALLONS OF ACID AT 80°F.