New Developments in Well Stimulation

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INTRODUCTION

Progress is essential to survival. In no other industry is this more pronounced than in the oil industry. With reserves becoming harder and harder to find, we must continually strive to increase our efficiency in recovering oil from known reserves in order to maintain an adequate oil supply to meet future demands. Increasing our efficiency is important for other reasons, too; one reason, perhaps closer to home, is to reduce production costs.

Operating companies and service companies are constantly trying new processes and techniques, sometimes with success, sometimes without. But the knowledge gained from each attempt supplies the information which is the basis for future progress.

The scope of this paper is limited to briefly describing several of the more recent developments in well stimulation.

BALL SEALERS

A method for temporarily plugging casing perforations has been provided by the perforation sealing process. Spherical sealing elements serve as free floating valves which are carried by the flow of treating fluid into the well, down the treating string, and, finally, against the casing perforations through which the treating fluid is passing. The sealers restrict the flow of fluid through the perforations, thus creating a pressure differential which causes the balls to seat and seal tightly against the perforations. The balls remain sealed against the perforations as long as a higher pressure is maintained in the well bore than in the surrounding formation.

Because only those perforations taking fluid are sealed, the process offers a positive method for treating previously unopened perforations. By completely isolating those zones which would normally take the treating fluid, the sealers divert the treatment to virgin zones which may never have been opened to the well bore. By staging the sealers during treatment, multiple zones may be treated in one set-up.

Fig. 1 illustrated a typical application of the process.

(a) Treating fluid enters the most permeable zone through lower perforations.
(b) Ball sealers, injected into line, follow flow of fluid down well.
(c) The flow of fluid to the permeable zone is blocked as balls seal perforations, and fluid begins to enter upper perforated zone.
(d) The upper zone is completely treated while sealers remain in place on lower perforations.
(e) The direction of flow is reversed and ball sealers drop to bottom of well. Both zones are completely treated.

Synthetic rubber, nylon, and rubber-coated nylon balls have been used in the process. Diameters of

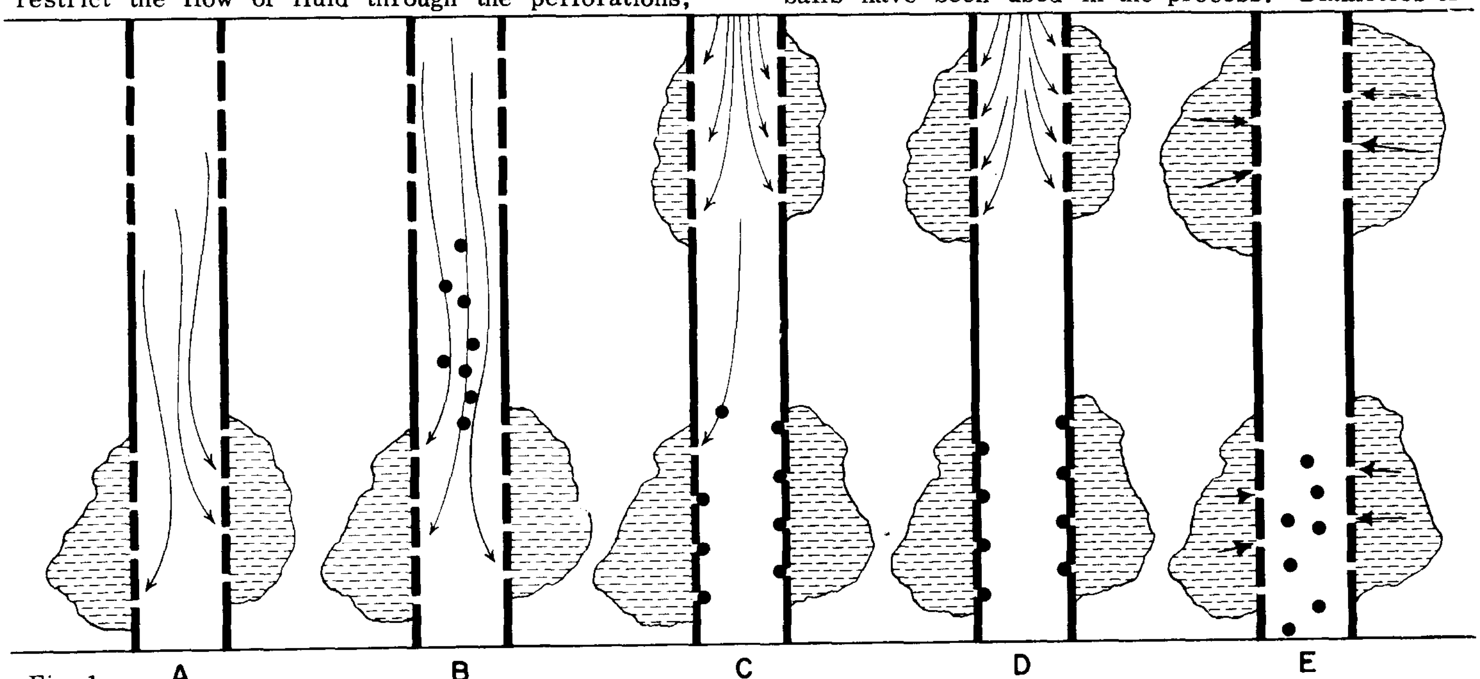


Fig. 1

the sealers have ranged from 5/8 inch to 1 1/4 inch. The most widely used sealers, however, have been 7/8 inch synthetic rubber balls.

The process provides a relatively inexpensive method for the selective treatment of cased zones. Its application can eliminate the expense of setting bridge plugs or running straddle packers. Because several zones may be treated in one set up, additional savings can be realized by reduced rig time and equipment rental. To illustrate, Table 1 shows a comparison of completion costs for one operator in the same field in Winkler County, Texas. The first three wells were treated by conventional methods, including use of packers and stage treatments. The last three were completed with ball sealers.

Table 2 presents typical stabilized production data taken from representative treatments performed in various oil producing areas. Also shown in the Table are the stabilized production potentials of offset wells, completed in the same formations with substantially the same number of perforations and intervals, but treated using conventional fracturing methods. These data serve to illustrate the effectiveness of ball sealers for stimulating well production and reducing completion costs.

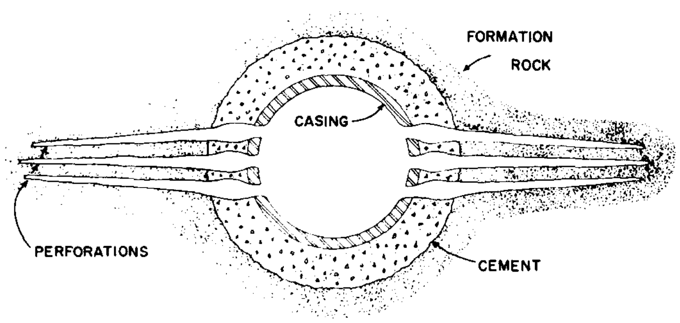
DOWN-HOLE FRACTURING BOOSTER

Instantaneous fracturing pressures can be created with a down-hole device containing a gas generating fuel. The tool is placed in the tubing string above a full opening packer, which is set above the zone to be treated. The hole below the packer is filled, via the tubing, with fracturing fluid. The tool is then triggered, by introducing into the fluid stream a plug which enters the tool and compresses a firing cam which detonates blank cartridges. This detonation initiates a controlled burning of the gas generating fuel. The gas creates an almost instantaneous pressure build-up and displaces the fracturing fluid from the well bore into the formation. The fracturing treatment is continued uninterrupted behind the propellant created surge.

The tool was developed to break down tight formations which usually resist ordinary fluid injection. In field tests with the device, pressure kicks reached 13,000 psi at the surface after the tool was fired.

CONTROL OF FRACTURES

Through the use of a small, expendable tool, horizontal fractures have been initiated at predetermined depths in cased wells. After initiation, the fractures are extended by conventional methods.



PATTERN FOR FRACTURE INITIATION - FIG. 2

TABLE 1

COMPLETION COSTS FOR ONE OPERATOR

WELL NO.	PERFORATING	TOTAL TREATMENT COST	RIG TIME	PACKER RENTAL	MISC. COST	TOTAL COST	INITIAL POTENTIAL
Conventional Method:							
1	$1,174.00	$14,984.00	$10,065.00	$4,056.00	$3,799.00	$34,078.00	152 bopd flw.
2	2,878.00	12,721.00	4,522.00	1,360.00	1,126.00	24,115.00	--
3	2,564.00	11,134.00	2,633.00	1,930.00	2,547.00	20,808.00	67 bopd flw.
Perforation Sealer Method:							
4	$2,447.00	$ 9,025.00	$ 500.00	$ 0	$ 850.00	$13,469.00	178 bopd flw.
5	2,343.00	7,740.00	725.00	0	700.00	10,508.00	120 bopd flw.
6	1,246.00	5,035.00	500.00	0	750.00	7,531.00	100 bopd flw.

TABLE 2

REPRESENTATIVE TREATMENTS WITH PERFORATION SEALING PROCESS

LOCATION COUNTY	FORMATION	PERFORATIONS	SEALERS	PREVIOUS PRODUCTION	PRESENT POTENTIAL	OFFSET POTENTIAL
Andrews, Texas	San Andres	6 sets, total 118 feet	375	13 BOPD, Pumping	120 BOPD, Flowing	50 BOPD, Pumping
Crane, Texas	Dune Grayburg	1 set, total 100 feet	400	New Well	400 BOPD, Flowing	100 BOPD, Pumping
Stephens, Oklahoma	Tussey Woodmansee	4 sets, total 84 feet	250	New Well	2044 BOPD	300 BOPD
Carter, Oklahoma	Tussey	2 sets, total 40 feet	300	48 BOPD, Pumping	604 BOPD, Flg.&Ppg.	50 BOPD, Pumping
Carson, Texas	Wolfcamp Dolomite	4 sets, total 47 feet	315	New Well	432 BOPD	336 BOPD

The initiation of the fracture is accomplished by creating a single set of six holes in a horizontal plane at the desired depth in the well bore. Two groups of three holes each are formed on opposite sides of the casing, as shown in Fig. 2. When hydraulic pressure is applied to this pattern, the maximum concentration of stresses is created in the horizontal plane through the center of the holes, thus causing rock failure in the horizontal plane.

The advantages of creating horizontal fractures at predetermined depths are numerous. For each zone of permeability a single, deep penetrating horizontal fracture provides more effective reservoir drainage than several shallow penetrating fractures. Through the control of horizontal fractures, oil zones quite close to water or to gas zones can be fractured without resulting in high water/oil or high gas/oil ratio wells.

The effectiveness of controlled horizontal fracturing can best be shown by citing a typical case. In a gas driven reservoir located on an anticlinal structure with the dome containing gas condensate and the flanks containing oil, conventional fracturing treatments invariably resulted in high gas/oil ratios, the lease average being approximately 10,000. By using the controlled fracturing technique, a well was completed for a potential of 440 barrels of oil per day and with a gas/oil ratio of only 2,960.

PREVENTION OF SCALE DEPOSITION

The deposition of sulfate and carbonate scale in the well bore and in the adjacent formation of producing wells has been reduced through the use of a sequestering agent. This agent is a granular, 12 to 40 mesh, complex phosphate.

Sequestering agents had been successfully used previously to prevent scale deposition in injection wells and, by annulus injection, on rods, pumps, and tubing in producing wells. Scale deposition adjacent to the well bore in producing wells, however, still remained a problem.

The present method involves injecting the slowly dissolving granular phosphate into the formation, along with sand, during a fracturing treatment. As the well is produced, the phosphate particles slowly dissolve in aqueous well fluids, sequestering the various ions in the brine and preventing their precipitation in insoluble form.

Control of Water Entry

The injection of an unusual surfactant composition mixed in crude oil, refined oil, or other suitable petroleum liquid has proved to be effective in selectively shutting off water entry into the well bore of a producing well. Since the treatment reacts only with formation waters, it does not affect the flow of oil from other sections in the producing interval.

During injection of this treatment, reservoir fluids are displaced in the vicinity of the well bore by the mixture of surfactant and oil. When injection is completed and the fluids begin to migrate toward the well, a water-in-oil emulsion is formed wherever water attempts to displace the treating fluid. This type of emulsion is formed because water becomes the internal phase in the resulting oil-wet pores. At each pore constriction, the water is broken into spherical droplets by the surfactant in the treated oil. These droplets act as ball-check-valves at each subsequent pore constriction to effectively block further water entry.

Because the reservoir oil is completely miscible with the treating fluid, its flow to the well bore is not interrupted. In fact, in the majority of cases, oil production shows a substantial increase after water production has been decreased. Water intrusion from coning, fingering, etc., increases the water saturation of the formation rock in the immediate vicinity of the well bore. The effective permeability of formation rock to oil is affected considerably by changes in water saturation; a reduction in water saturation will increase the effective permeability to oil. Therefore, by reducing the flow of water to the well bore, the water saturation in the immediate vicinity of the well bore is reduced, subsequently causing an increase in the rate of oil production.

TRENDS IN FRACTURING

During the early stages of the fracturing process, treatments were usually conducted under packers via tubing at low injection rates, rarely exceeding 10 barrels per minute. The fracturing fluid was a viscous oil-base fluid, usually gelled kerosene, carrying suspended sand particles. Treatment volumes were normally less than 10,000 gallons. The fracturing techniques of today bear little resemblance to the early treatments. The use of sand grains as propping agents is perhaps the only part of the process which has not undergone severe change.

The majority of treatments are now conducted down casing at high injection rates, averaging 20 to 30 barrels per minute. With increased injection rates, high viscosity carrying fluids are not necessary to suspend the sand particles because the sand can be adequately carried by the fluid velocity alone. A carrying fluid with a high viscosity is even detrimental in that it creates high friction pressures which must be overcome by additional horsepower requirements.

Fig. 3

High Viscosity Fluids

High viscosity fracturing fluids, such as acid/oil emulsions, have one big advantage over low viscosity fluids. This advantage is found in less fluid loss to matrix rock during the fracturing treatment. However, the fluid loss of low viscosity fluids may be controlled through the use of fluid loss additives, which serve as temporary plugging agents.

Crude oils, refined oils, and low viscosity gelled crudes comprise the bulk of fracturing fluids being used, but the use of water in fracturing is gaining popularity in many areas. Acid/kerosene emulsions are still popular in dolomite and limestone reservoirs.

Treating volumes now average 20,000 to 30,000

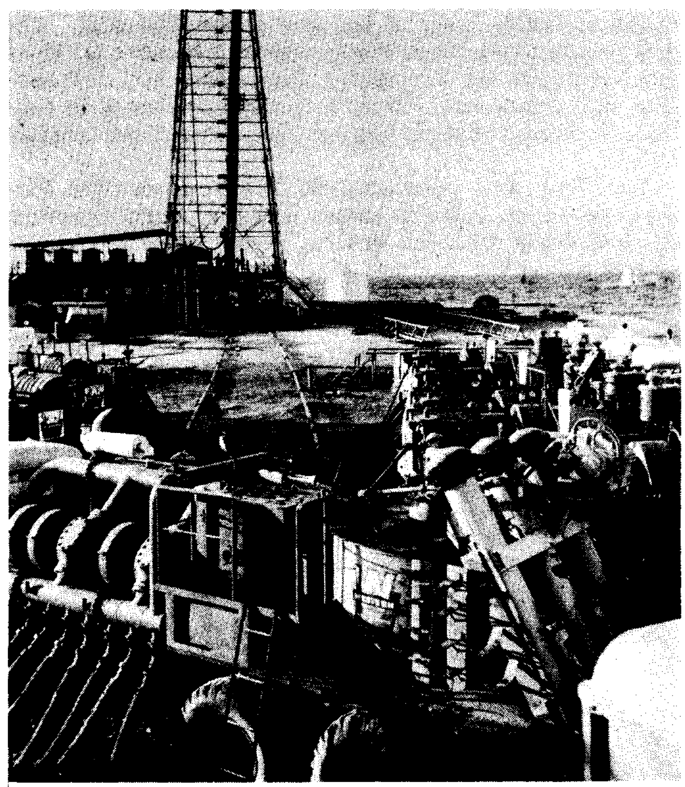


Fig. 4

gallons, and volumes as high as 100,000 gallons are not uncommon. With the excellent results which are being obtained, we can expect the emphasis in fracturing to remain on increased injection rates and increased volumes.

Fig. 3 shows a typical fracturing job being performed in early 1952. A recent job with 10 super charged pumping units is shown in Fig. 4. These figures clearly illustrate the changes which have taken place in fracturing treatments, both in equipment and size.

FUTURE OUTLOOK

This paper has described only a few of the many developments which have been made in well stimulation. Every day some new technique or method is tried in the oil field. Each of these trials leads toward the recovery of more oil.

Well stimulation processes have advanced a long way from the early acid treatments of the 1930's. With service and operating companies working hand in hand, progress in well stimulation will continue to advance at a rapid pace.

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