LOG YOUR TREATMENT INTO PLACE

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INTRODUCTION

Today's demands upon the oil industry call for all-out effort to maintain or increase the production efficiency of both old fields and newly discovered reservoirs.

These increasing needs must be met from producing horizons that present a multiplicity of both natural and incurred production limiting conditions (i.e., cement channels, vertical fractures or erosion, soluble or low pressure zones, poor permeabilities and porosities, water breakthrough, scaling, etc.). Many of these conditions must be altered to obtain any significant change in production.

Hydraulic application of stimulation or plugging agents is used extensively in remedial operations. This technique has the advantages of providing transport of large volumes of material to the zones, pressures for application, and compatability with a variety of wellbore mechanics.

Selectivity of placement by this method is poor, since the hydraulic influence is exerted upon any and all exposed areas, and the pumped-in materials frequently enter the wrong interval, causing damage, or are rendered ineffectual from near-total loss.

Confinement of treating materials by mechanical means has been attempted with varying success. In-hole packers and/or fluid blocking agents seem fairly effective in original completions where borehole damage is slight, but any erosion or extensive fracturing beyond the perimeter of the wellbore or behind the casing makes zone isolation difficult, if not impossible.

Staging and monitoring after each stage provides evaluation of results, but no control of selectivity is provided during the pumping operation. Inadequate blocking can result in poor completion and loss of treating efficiency or, in case of permanent plugging attempts, complete loss of a zone or well.

Early attempts to quantitatively determine the distribution of fluids injected into subsurface zones led to a method of monitoring the interface of separate injection streams in a wellbore and assigning proportional injection above and below the interface by observing the respective pumping ratio at the surface. This method was abandoned as a profile technique because of the time and expense involved to establish stabilization after each new distribution.

PREPARATION AND EQUIPMENT

The principle of proportional control of separate fluid columns has been adapted to allow placement of treating materials into a selected zone with one stream while protecting other zones with a control fluid stream. The mechanics and application are as follows.

Preparation

The well is prepared for treatment by installing tubing to total depth or below zones to be treated. Tubing should be free of obstruction to allow clear passage for tools below the point designated for the fluid interface to be formed. The surface connections must allow for simultaneous pumping into the tubing and the annular space. Packers may be run for special application, but better results have been seen with the annulus and tubing in communication.

Surface equipment must have separate systems for the annulus and tubing pumping operations, including provision for the mixing and storage of the treating materials and radioactive markers in their respective fluids. Connections for lubricating the logging tools and line into the well should be installed to allow operation under pressure.

Equipment

Monitoring (logging) equipment consists of surface recording equipment and a dual detector gamma-ray tool, with the detector spacing no more than five feet (standard spacing for most profile tools.) Tools may be run into the well without a downhole ejector and reservoir for radioactive material; but some applications call for a secondary interface to be formed, or setting preliminary pumping rates using standard profiling methods. A full string of tools (dual detectors and downhole ejector) is needed in these instances.

Pumping equipment should be capable of maintaining maximum desired rate with either the annulus or tubing systems (calculated from treating volume and pumping time requirements), and sufficient storage for reserve fluid should be arranged before commencing operations.

OPERATION

The operation is performed by dividing the total pumped-in fluids between the annulus and tubing, either of the streams carrying the treating fluids and the other used as a control volume. The treating or plugging agents are passed into the desired interval but are prevented from entering the zone to be protected by pumping the control stream at a rate sufficient to preclude the entry of the treating stream into the second zone. The annular stream (whether treatment or control) is tagged with a radioactive marker which allows identification of the fluid interface between the two streams. The fluid interface is maintained at the desired position by varying pumping rates of one or both of the streams of fluid.

Treatment is initiated by placing the logging tool downhole, stationing it at a point 100-200 ft above the desired position of the fluid interface. Pumping in both the annulus and tubing is commenced using only water (or oil, if formation dictates) with none of the treating agents added. (The annulus stream must be tagged to allow identification). As the R/A tagged annulus stream reaches the monitoring tool, the tool is then lowered with the fluid progression, following its progress to the preselected point for the interface.

The fluid interface is held at the selected interval by varying the rates of either or both of the injection streams.

Predetermined rates for treatment should be established with the stream selected for treating and the interface held constant by adjusting the control volume.

The "dummy" or test pattern should be maintained for at least 30 minutes to ascertain that initial fill-up will not override the control or exceed predetermined pressure limitations.

Before shutting-in the test stage, interface control should be checked by increasing or decreasing one or the other of the pumping rates and monitoring for a corresponding movement of the interface. Should the interface remain in the same position, the total volume of both streams is balanced at that point and no actual control is being exerted. The test pattern must then be repeated using different rates or temporary permeability-reducing additives to establish positive control.

The actual treating materials are introduced in the proper stream after positive control of the interface, rates, and condition has been established. The additional viscosity caused by the additives may tend to displace the interface due to slightly higher pressures at the formation face, but increasing the volume of the control stream will maintain position in most instances.

Continuous monitoring of the interface position is necessary; and should the position begin to change, prompt action is needed to prevent momentary loss of control.

Application to wells having only two zones may be accomplished with a single operation and basic preparation, but multiple zones must be treated in stages. Treating zones between zones to be protected necessitates blocking the lower zone with sand fill or blocking agent before treating.

Wells that support a pressured column of fluid to the surface afford near-instantaneous control of interface position by varying either the treating or control volumes.

Wells with low-pressure zones are subject to time lag while fluids are falling and tend to go on vacuum, aborting the treatment. Control may be maintained by including a back pressure valve at the end of the tubing string to support a full column of fluid. Pumping rates are held constant in the annulus and total interface control is exerted by adjusting the tubing pumping rates.

Additional control may be accomplished by introducing selected agents into either of the fluid streams to increase viscosities or to block zones. These may be included in the entire column or in stages, as the situation demands, and their effect monitored during the pumping process. Absolute control of treating stages can be observed and adjusted during pumping operations to effect more complete treating of selected intervals.

TECHNIQUE AND APPLICATION

The logging unit is the nerve center of the job, and both the logging and treating engineers should direct their operations from this point. Each job should be preceded by a briefing session on location to ensure that all personnel are aware of the purpose and sequence of the operation and the importance of coordinated action. The incidence of unsatisfactory results can be attributed more to inattention than all other factors combined.

Some examples of this technique and its application are presented below.

Well "A", Goldsmith Field

This producing well, in the San Andres formation, was an openhole completion with bottom water through local fractures from a zone approximately 40 ft below total depth. The recommended treatment consisted of 2000 gallons of permanent polymer followed with 50 sacks cement, then displacing the cement to leave 20 ft in the wellbore. The polymer was pumped with staged catalyst for progressive setting times.

The fluid interface was held within two feet of position with slight increases in annulus rate and pressure as polymerization progressed. Approximately 2 bbl of cement slurry had been pumped when continued polymerization increased pump-in pressures and caused the interface to move uphole rapidly. Annulus rate was increased to force interface back to position and protect the producing zone.

As the interface moved back to position, the treating engineer signaled for annulus rate reduction to hold position properly, but the pump truck operator had his head-set off; and the interface of polymer and control stream continued downhole to total depth allowing control water from the annulus to dilute the last stages of polymer.

The pump operator's attention was regained and interface control reestablished for the cement phase, but the diluted polymer did not properly seal the smaller fractures and the plugging attempt was unsuccessful.

In summary, the before-and-after performance of the well was:

Production before treatment:
204 bbl water, 7 bbl oil.
Production immediately after job:
165 bbl water, 8 bbl oil.
30 days after treatment:
195 bbl water, 7 bbl oil.

Proper technique and attention to operating sequence can produce more desirable results.

Well B, Slaughter Field

This injection well, an openhole completion in the San Andres formation, was operating at 300 BWPD at 900 psi surface pressure. The total injection was leaving the wellbore in the bottom 15 ft of the well with 36% continuing past total depth.

The recommended treatment was similar to that of well "A". Fifteen-hundred gallons permanent polymer (staged with progressive catalyst) was used with 50 sacks of cement following the polymer. Tubing was set 5 ft above total depth and the interface formed at 15 ft above total depth.

The entire job was pumped at 3/4 to 1 BPM down tubing and 2-1/2 BPM down the annulus (control stream).

Cement was flushed from the tubing and the tubing was pulled up 60 ft with pressure held on the well.

The well was placed back on injection 18 hours later. No injection profile was run immediately after treatment, but the profile 30 days after the job showed good injection distribution over the entire pay interval with no fluid leaving at total depth.

The current injection rate is 350 BWPD at 1400 psi surface pressure.

Thus, it is seen that individual well conditions often dictate various changes in both technique or sequence and materials used.

Well "C", Slaughter Field

This injection well was an openhole completion in the San Andres formation with an injection of 320 BWPD at 900 psi surface pressure. Twenty percent of the fluid was channeling up 60 ft from the casing seat with 80% leaving the wellbore at total depth.

To avoid using cement down the annulus to hold the treatment in place, it was recommended that a two-stage treatment consisting of 1000 gal. silica gel in the upper channel and 2000 gal. silica gel in lower fluid loss zone be used. Both stages were designed with the last 250 gal. of silica gel mixed with silica flour to form a slurry for additional shear strength in place.

During treatment, the interface for the upper channel was established five feet below the casing seat and the gel was pumped down the annulus and displaced entirely. The well was shut-in overnight and the second stage was pumped down the tubing the next day.

A profile run 30 days after treatment showed the upward channel completely blocked, with 27% of the injection fluid leaving the wellbore at total depth. The remainder of the injection was distributed over the pay interval.

This is an example of the precision control afforded by these techniques which, in turn, save much of the clean-out expense normally associated with remedial operations.

Well "D", Alvord Field, Wise County

The production well was cased and perforated (Strawn formation) with production of 100 BPD; no oil. Production analysis survey (R/A and temperature) showed water breaking into the well from a zone 170 ft above the perforated interval. Several attempts to squeeze by conventional means failed because of a strong water-drive from the contributing zone. Three-thousand gallons of Injectrol "S" was placed by the Isotrol method, pumping it down the annulus with the material. The interface was established 5 ft below the top perforation and the material was displaced from the wellbore before shutting in the well. The well was placed back on production 48 hours later (no clean-out) and is currently producing 240 BOPD and 8 BWPD. Several similar jobs have been done in the area since this treatment, and all have been successful.

No fracturing or acidizing examples are cited in this writing because of a lack of specific prior history for comparison. Acid treatments and fracturing operations can be controlled by the same techniques, and a large number have been done to date. Customer reports indicate better than expected results in all instances where their experience factor allows comparison.

Cost of these controlled operations varies widely with the type and volume of materials used; but the individual cost of monitoring and control remains at an average of 15-20% of total job cost (less if large volumes of materials are used). A significant portion of the monitoring cost is for the radioactive material used to tag the volume of fluid pumped in the annulus and this is dictated by the volumes used. Average monitoring cost on a 5000-ft San Andres polymer job is $900-$1200 with radioactive material costing $250-$400. In most instances, the increased efficiency and control of the operation more than offset the slight relative increase.

MATERIALS AND FLUIDS

This technique was originally designed for use in permanent polymer plugging operations, but experience has shown that it may be used with any of the excellent treating agents supplied by the various pumping companies.

Little or no alteration of mixtures is necessary to adapt to this controlled application except that consideration should be given to the logging tool in place downhole during pumping. Solid blocking agents too large to pass the clearance afforded with the tool in the tubing should not be introduced into the tubing stream, and slurries and viscosities must be kept light and low enough to allow desired pumping rates without excessive abuse or loss of downhole tool; i.e., during down-tubing sand frac, the tool must be run in the annulus to prevent abrasion or to prevent the tool being "pumped off" the line by high fluid velocities. To date, the process has been used with permanent polymers, cement, rock salt, benzoic acid, HCl acid, sand, and a variety of viscous fluids with only a single instance of tool loss. A pin collar at the bottom of the tubing retained this tool which was then recovered after completion of the operation.

ADVANTAGES

This method allows constant monitoring of downhole behavior during pumping operations. An example is multi-zone stimulation. Stages are pumped and blocks placed with positive control. Should a calculated block not be sufficient, more block may be added for desired results, or the control stream varied to move the effective interface to the desired position for the next stage.

It permits controlled application of spearhead or breakdown acid stages to assure proper zone intrusion and to reduce the incidence of communication and/or channeling.

This method provides precise control of plugging and squeeze operations where zones are in close proximity. Minute control (2 ft interval selectivity) allows blocking of channels or thin zones immediately above or below zone of interest without affecting the prime interval, thus eliminating drillout and recompletion procedures.

A variety of material selection to allow tailoring of the treatment to individual well conditions is afforded.

Pre-treatment investigation is permitted which allows on-location procedure change for more efficient treating.

The method provides control of treating fluids behind communicated casing.

DISADVANTAGES

There are three disadvantages in this method: some down-tubing rate restriction results with the logging tool in the wellbore (the maximum down-tubing rate employed to date has been 3-1/2 BPM); pressure restrictions result due to the casing and tubing being in communication (no packer), and separate pumping systems are required for tubing and annulus.

SUMMARY

The need for selective control of pumped fluids has been satisfied by Isotrol, the interface method of monitoring pumping operations. The system is applicable to almost all materials and conditions and can afford protection of zones, and provide constant control and savings in time and efficiency during application. Production results attest to the advantages of these methods, and experience has allowed the industry to extend the applications into almost all phases of pumping operations. Carefully planned and coordinated operations can save time and money and allow remedial operations heretofore untried or unsuccessful.