Remedial Control of Injection Water

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INTRODUCTION

The efficient use of available water has become extremely desirable in recent years, due to the limited supply of compatible injection water in many areas of the Southwest.

The ever present demand that produced waters be properly disposed of so that our ecology will not be damaged and the mounting costs of producing, treating and re-injecting produced water have also focused attention on new methods and techniques for controlling injection water for more effective utilization of the available water.

The major problems encountered in waterfloods which have caused the waste of resources — water, horsepower, equipment, etc. — have been the lack of confinement of the injected water to the zones containing recoverable oil and the premature water-out of producing wells because of this lack of confinement or *control.*

Specifically, control must be exerted over injected water which:

1. Channels out of zone into barren zones.
2. Channels out the bottom of the wellbore into the unknown.
3. Communicates directly to producing wells through directional fractures or thin high permeability zones.

The usual cause for control loss in water injection wells may be described as *water's affinity for water.* High relative permeability to water combined with a lack of isolation of zones caused by deteriorated cement or open hole, allows injected water to seek the path of least resistance—the zones of higher relative permeability to water.

The methods used in analyzing fluid movement in water injection wells — radioactive tracer and velocity profiles and temperature decay surveys — provide graphs of the relative permeability to water. These graphs are used to express the vertical distribution of injection water as percentage per foot of zone. The combination of surveys offers the best method of defining the control problem in individual wells.

Radioactive tracer and temperature decay surveys have shown that water is re-injected into the water producing zones of producing wells which have been prematurely watered-out from bottom or through thin zones. These zones of water breakthrough are certainly zones of high relative permeability to water.

MATERIALS

Various materials have been used in attempts to solve the problems of control found in waterfloods — cement, silica gels, epoxies, water glass, leather flock and other solids, and polymer slurries — without a great deal of success.

This work will confine itself to one material, a polymer gel, and the techniques used for its successful application.

The blocking material used is a solution of water-soluble monomers which has a density of 8.67 pounds per gallon and a viscosity of 1.20 centipoise. These physical properties very closely approximate those of most injection waters and, therefore, offer the best possible chance for duplicating the flow pattern of the injected water. The solution, when properly catalyzed for a given time and temperature condition, disperses into the permeability of the zone and polymerizes instantly. The polymerized solution forms an impermeable gel within the permeability to tie the zone together. The gel barrier formed is insoluble, nonporous and provides enough added strength to the zone to support remedial treatment pressures, if necessary. The ultimate strength of the polymer block depends on the depth of invasion.

TECHNIQUES OF PLACEMENT

The properties of the solution — density 8.67 pounds per gallon, viscosity 1.20 centipoise—plus the high permeability to water existing in thief zones of injection wells and water breakthrough zones in producing wells provide the vehicle for accurate placement of the solution which forms the permeability block.

Normal Injection Well Application

Most water injection wells containing thief zones as defined by injectivity profile and decay temperature surveys can be treated very easily using the monomer solution.

Ordinarily, no prior work is required by pulling unit. The injection well is shut-in, a pump and mixer unit hooked up and a fresh water pad, equal to the volume of the tubing, is pumped. Then the material is mixed and catalyzed for the proper pumping time and temperature. The solution is pumped and displaced into the offending zone and the trailing interface of the solution left at a depth defined by the injectivity profile. The well is shut in for at least twelve hours then returned to normal injection.

Abnormal Injection Well Application

Some injection wells contain thief zones of almost equal amounts of good and bad water distribution over approximately the same vertical footage of wellbore.

These wells can be treated satisfactorily by utilizing a controlled interface method of placement. The controlled interface is accomplished by removing the packer and re-running the tubing to a depth below the point at which the interface must be controlled. The well must be replaced to injection and allowed to restabilize (pressure and rate).

The treatment is accomplished by adjusting injection rates down the tubing and annulus while logging inside the tubing. A burst of radioactive I-131 is ejected inside the tubing and pumped out and up into the annulus to the point of interface control. Pump rates are adjusted so that the interface does not move.

Once the interface control is assured, the solution is mixed and placed down the annulus using the same procedure described in the previous section.

Producing Well Application

The work done on watered-out producing wells becomes more expensive since a pulling unit is necessary to pull rods and tubing and run packers; and at times, clean-out to total depth is required. The remedial work of plugging off water in producers is essentially the same as for an injection well.

The producing well should have a production survey run on it to identify the water zone, if possible; however, in most cases a pump-in tracer has been adequate to supply the information necessary for treatment design. The only logical reason for this happy circumstance — High relative permeability to water in the watered-out zone.

When the zone of water production has been identified and isolated, the solution can be placed in the same manner as in water injection wells.

Special Applications

Placement of materials in wells which have no surface pressure (vacuum) require a static fluid level measurement using temperature logs or fluid level shots. These measurements supply necessary data for displacement calculations.

Placement of materials in wells containing abnormally large open hole sections requires the solution to be tagged with radioactive material and the trailing interface be logged into place. This technique is also used in the 'vacuum' situations.

TREATMENT VOLUME DETERMINATIONS

Original calculations for treatment volume were made using Darcy's equation for radial flow. There are very few, if any, radial injection patterns encountered — most are directional. Calculated treatment volumes have been tempered by this directional situation and four years' experience.

The design of treatment volume is now calculated by multiplying the vertical distribution of water loss by the factor 75 gallons per foot in fractured zones and 100 gallons per foot in 10 per cent porosity. These volumes would provide 6 feet of invasion into the zone of injection.

In designing for volume of treatment for 10 feet of invasion, the factors used are 100 gallons per foot in fractures, 235 gallons per foot in 10 per cent porosity and 440 gallons per foot in 15 per cent porosity.

RESULTS OF SOLUTION APPLICATIONS

The results of remedial control treatment can be evaluated quickly by changes in profile redistribution and produced water reduction. The most significant measure of success—increased oil in the tank — requires more time. Occasionally, small increases in oil production are noted, but longer periods of time are required to bank more oil in newly created zones of distribution.

The results are observed quickly after remedial control treatments are applied to producing wells.

Figures 1 and 2 are self-explanatory and represent typical applications in water injection wells.

Figures 3 and 4 represent a typical injection well problem and show two approaches to its solution. The well in Fig. 3 was plugged back with sand to protect the lower zone, while the upper zone was treated. The well in Fig. 4 was treated using the controlled interface method to protect the lower zone while treating the upper thiefing zone.

Figures 5 and 6 represent typical producing well problems. The wells (four) represented by Fig. 5 were simply surveyed with pump-in tracer and treated with 2000 gallons of the polymerizing solution. They were shut in overnight and returned to production the next evening.

The four wells are now producing an additional 700 to 750 barrels per day with some reduction in water production.

Figure 6 represents a group of three wells in which the upper section of each could not be treated for stimulation until the lower losses were plugged with the polymerizing solution.

CONCLUSIONS

The effective use of injected water can be substantially improved by careful analysis of radioactive profiles and decay temperature surveys to accurately identify the control problems in water injection wells and correcting them by properly designed placements of the polymerizing solution.

More oil and reduced water production can be achieved by correctly eliminating water breakthrough zones in waterflood producers.

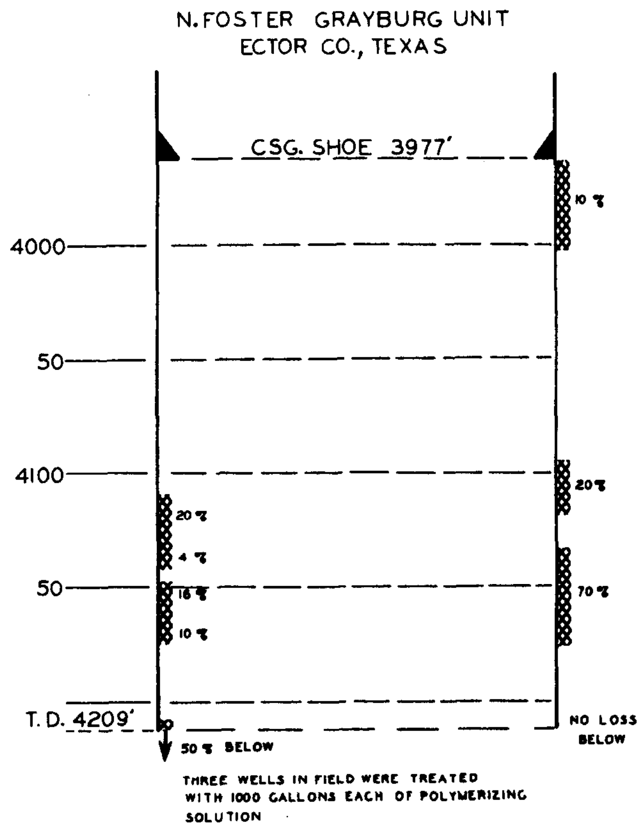

FIGURE 1

TYPICAL INJECTION WELL APPLICATION

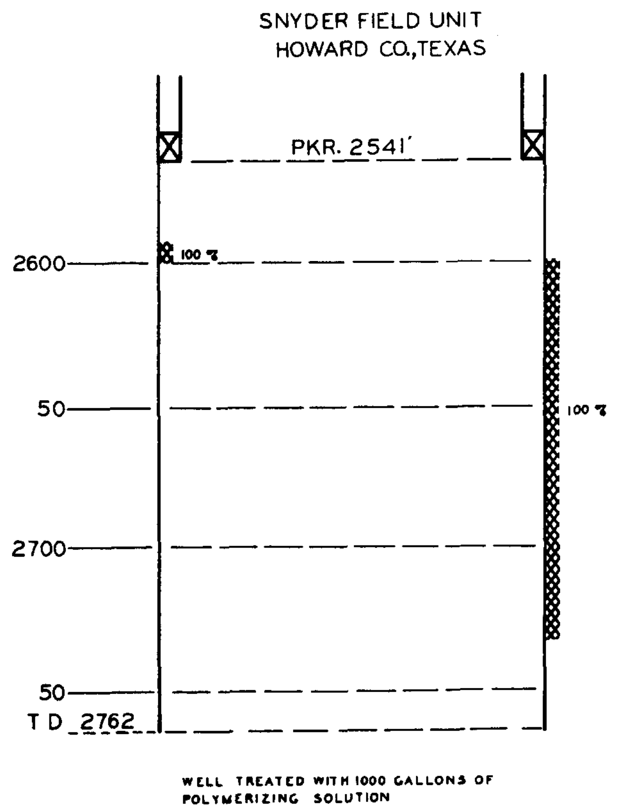

FIGURE 2

TYPICAL INJECTION WELL APPLICATION

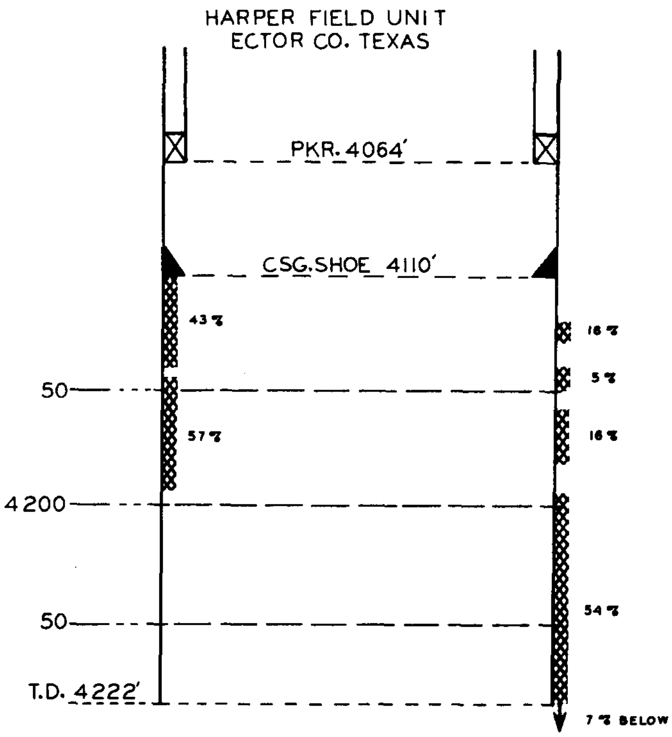

FIGURE 3

TYPICAL INJECTION WELL APPLICATIONS

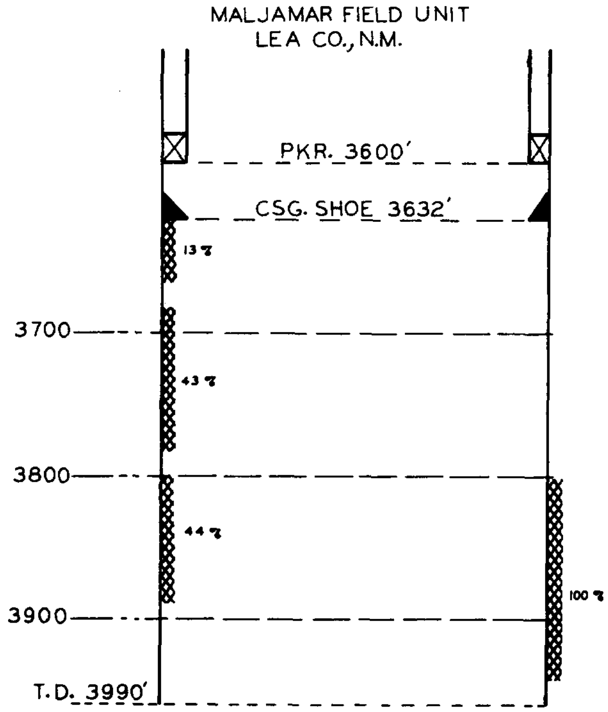

FIGURE 4

TYPICAL INJECTION WELL APPLICATIONS

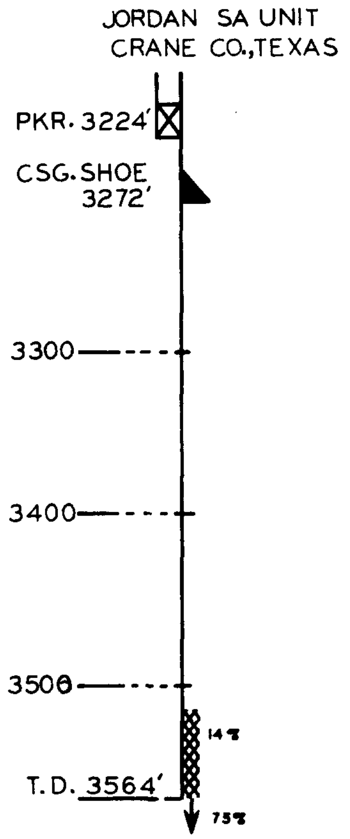

FIGURE 5

TYPICAL PRODUCING WELL APPLICATION

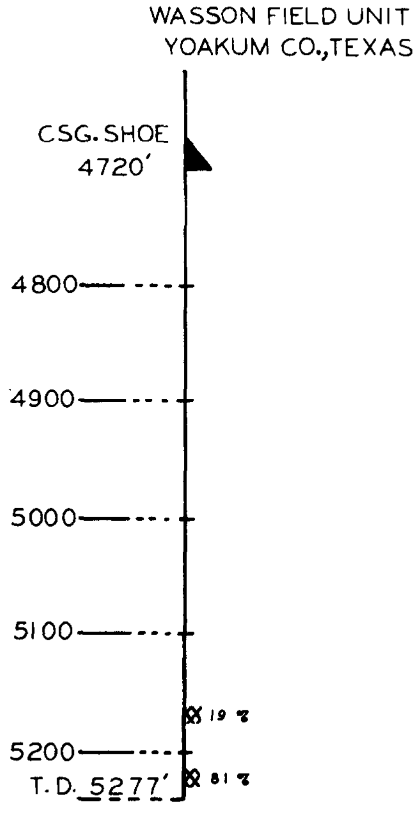

FIGURE 6

TYPICAL PRODUCING WELL APPLICATION