United States Patent Office 2,770,306
Patented Nov. 13, 1956

2,770,306

SAND CONSOLIDATION

Roscoe C. Clark, Jr., Midland, Tex., assignor to Stanolind Oil and Gas Company, Tulsa, Okla., a corporation of Delaware

No Drawing. Application June 25, 1954, Serial No. 439,480

4 Claims. (Cl. 166—33)

This invention relates to the treatment of wells, such as those producing oil and gas, or water, wherein the fluid-producing formation is an unconsolidated or poorly consolidated sand. More specifically, it is directed to the consolidation of such formations by injecting into them a resin-forming liquid capable of transformation into a solid resin, binding the loose sand particles firmly together.

The use of "liquid plastics," as they are popularly known, for sand consolidation in oil and gas wells has been practiced commercially for a number of years. Success is achieved in some instances, while failure results in others. The failures generally have been either not obtaining consolidation of the sands or too greatly lowering the permeability of the formation. Almost complete plugging occurs in some instances.

Two principles of operation have generally been relied on to retain some permeability in a sand being consolidated. According to one, the sand is completely filled with a liquid, consolidating plastic which wets the sand grains, and the excess liquid plastic is driven out of the pore spaces before solidification occurs by flushing with oil. A plastic film remains on the sand grains and finally hardens, binding the grains together at their points of contact and leaving the pore spaces between grains open for fluid flow.

In the other commonly used method, a mixture of liquid plastic and a diluent miscible therewith completely fills the pore space in the sand, but, due to the presence of the diluent, the volume of the solidified plastic is only a fraction of the volume of the liquid mixture. Solidification takes place on the surfaces of the sand grains, cementing them together at their points of contact, while the diluent is rejected and fills the intervening pore spaces. Thus, the "shrinkage" of the volume of the solid relative to the volume of injected liquid guarantees porosity.

The failures that occur have generally not been explained, but they are probably due to actual well conditions being in some unknown respects different from what they were assumed to be. The most costly type of failure is that where too great a reduction in permeability occurs, as expensive measures may be required to restore sufficient permeability for fluid production. If the failure is simply that the sand remains unconsolidated, then other control means such as gravel packing or screens with small openings may be resorted to.

In view of the foregoing, it is a primary object of this invention to provide an improved method for consolidating loose sand formations with minimum loss in permeability, using a composition which includes a resin-forming liquid capable of wetting the sand formation and of transformation into a solid, binding the formation particles together. A further object is to provide, for consolidating loose sands while retaining therein substantial permeability, an improvement in treatments of the second type mentioned above, wherein the solidified resin has a substantially smaller volume than the injected liquid mixture. Other and further objects, uses, and advantages of the invention will appear as the description proceeds.

Briefly stated, I have found that the choice of diluent added to the resin-forming liquid before injecting into the formation to be consolidated strongly influences both the consolidation or strength obtained and the resultant permeability. Whereas diluents such as methyl, ethyl, or isopropyl alcohol, miscible in the resin-forming liquid, have been employed in the prior-art procedures, I have found that much improved results are obtained by using immiscible diluents such as oil or water mixed or emulsified with the resin-forming liquid. Furthermore, I have found that the choice of oil or water as the diluent depends on the wetted condition of the sand to be consolidated. That diluent is chosen which, in the presence of the plastic, has the least wettability for the sand in question.

In other words, if the sand to be treated tends to be water-wet, a mixture of resin-forming liquid and oil is used since, of these two components, the resin-forming liquid is able to displace enough of the water film on the sand to effect consolidation, while the oil remains in the pore spaces and maintains them open. On the other hand, if the sand tends to be oil-wet, a mixture of water and resin-forming liquid is used, and the water remains in the pore spaces, while the resin-forming liquid wets and consolidates the sand particles.

This is borne out by the following test results comparing various plastic consolidation procedures on samples of five unconsolidated producing sands from different oil fields in Texas. For testing, the sand samples were placed in standard core holders provided with screens at the end, in a condition as nearly as possible "as received," to preserve in-place wettability characteristics. Screen analyses of these sands gave similar particle-size distributions, the minor differences in such distributions being much too small to account for the variations in results of consolidation procedures.

In these tests four different liquid plastics or resin-forming liquids were used, respectively designated in the table as plastics A, B, C, and D. Plastics A, B, and C were commercial compositions designed for the specific purpose of consolidating loose sands. Plastic D was a commercial oil-well plastic normally used primarily for cementing or plugging purposes. In each case the test procedure, after placing the sand in the sample holder, was to measure the sample permeability and then inject and cure the plastic composition for the requisite length of time. If the sample was then sufficiently consolidated, its permeability was again measured, as well as its compressive strength. In the results shown in the table, the final permeability retained is stated as a percentage of the permeability measured before consolidation, and the compressive strength is given in units of pounds per square inch.

Table

Source of Sand	Test No.	Consolidating Plastic Used	Percent Perm. Retained	Compressive Strength
Barbers Hill Field	1	B	2.4	570
	2	C	29.0	712
	3	D+#10 oil	low	low
	4	D+50% water	58.5	570
Martha Field	1	A	1.4	860
	2	B	2.7	760
	3	C	15.7	807
	4	D+50% methanol	1.75	750
	5	D+50% #10 oil	.4	1,380
	6	D+80% #10 oil	1.2	1,250
	7	D+50% water	45.3	1,805
South Houston Field	1	B	1.0	617
	2	C	0	570
	3	D+65% #10 oil	13.0	475
	4	D+75% #10 oil	16.0	427
	5	D+80% #10 oil	17.0	50
	6	D+50% water	4.7	1,472
Goose Creek Field, 3,000′ depth.	1	A	1.5	500
	2	B	0	475
	3	C	2.2	475
	4	D+50% methanol	not meas.	0
	5	D+25% methanol	21.0	500
	6	D+75% #10 oil	35.0	855
	7	D+50% water	4.4	25
Goose Creek Field, 4,200′ depth.	1	B	0	380
	2	C	0	570
	3	D+75% #10 oil	24.0	142
	4	D+50% water	5.7	1,185

Considering the significance of the results shown in this table, the Barbers Hill sand will be seen to have given fair results with commercial plastic C. The very poor results of test 3 using oil as a diluent and the much improved permeability of test 4 using water as the diluent quite clearly indicate that this sand is primarily oil-wet.

Similarly, the sand from Martha Field is predominantly oil-wet; and test 4 shows in addition that the use of a miscible diluent, methanol, in the plastic composition is of no assistance whatever in this instance for increasing the retained permeability after consolidation.

The South Houston sand, on the other hand, is apparently more readily wetted by water than by oil, although test 6 shows that it is not so strongly wetted by water that it cannot also be wetted by the plastic to produce good compressive strength. Test 5 demonstrates that an upper limit of percentage of diluent is being approached, where the amount of plastic present is becoming so small as to be just barely enough to create a consolidation effect.

The two Goose Creek sands are like the South Houston sand in being primarily water-wet, and, by tests 4 and 5 in the 3000-foot sand, it is again shown that a miscible diluent is not only ineffective in this instance, but may actually prevent the bonding of the sand particles by the plastic. The high compressive strength of the 4200-foot sand (test 4) is not clearly understood when compared with the low strength obtained in test 7 on the 3000-foot sand. It seems apparent, however, that even the water-wet condition of the 4200-foot sand did not prevent good wetting by the plastic, whereas wetting by the plastic was inhibited by the water in the 3000-foot sand. In both of these sands there is no doubt that oil is the superior diluent compared to either water or methanol.

In partial confirmation of the theory of operation and results which have been set out above, consolidated samples of some of these sands were treated by filling the pore space remaining after consolidation with a second settable plastic containing a dye of distinctive color. Thin transparent sections were then prepared and examined under a microscope. This examination clearly showed the consolidating plastic to be concentrated at the points of contact between sand grains in what may be termed a state of pendular saturation, while the plastic containing dye appeared prominently in the pore spaces between grains. The coating of consolidating plastic on the grains appeared to be quite thin except at the points of contact.

The resin-forming liquid used in the practice of this

invention can be any of the undiluted commercial liquid plastics adapted for oil-well use. These are, at the present time, generally partially condensed phenol-aldehyde type resins prepared in the form of one or two stock liquid solutions which are to be mixed just prior to the time of use. Varying amounts of an alkali catalyst such as sodium hydroxide are added to the mixed liquids depending on the temperature at the well-formation depth and the desired setting time, to control the setting of the liquid to a solid. As examples of the thermo-setting resin forming liquids and their manner of use in wells are described in detail in a number of places, such as in U. S. Patents 2,485,527, 2,541,688, 2,674,322, and 2,674,323, no further description of the plastics is believed necessary here.

When oil is to be used as the diluent, the oil chosen should have a substantial viscosity, as otherwise separation of the oil and liquid plastic mixture into two separate phases may occur too rapidly. Thus, a crude or refined oil of about the viscosity of SAE #10 motor oil or slightly higher is preferable.

In use the oil and liquid plastic are thoroughly mixed and form a semi-stable emulsion upon vigorous agitation just prior to being put down a well tubing. Enough following liquid is pumped down the tubing to displace the mixture of oil and plastic into the formation, where the mixture is held stationary under pressure until completely solidified. Thereafter, the well is placed on production, and the diluent oil is driven out of the pore spaces by the reservoir fluids.

When water is to be used as the diluent, it is first preferably treated by adding to it a soluble emulsifying agent. For example, about two per cent by weight of a sulfonated fatty alcohol such as Orvus WA, or any of a number of similar agents, is first dissolved in the water, and the resulting solution is then vigorously agitated with the catalyzed liquid plastic to emulsify it just before introduction into the well tubing. The emulsion is displaced from the bottom of the tubing into the formation to be consolidated by a following liquid and held therein until set in exactly the same manner as is the mixture of plastic and oil.

Where the wetted condition of a sand formation is uncertain, therefore, the preferred procedure of this invention is first to obtain samples of the sand and subject them to consolidation by mixtures of oil and plastic and of water and plastic, respectively. The optimum proportion of plastic to diluent can also be determined by such tests and will generally be found to lie within the limits of about 20% to about 80% and is preferably from 25% to 50%. Less than 20% diluent generally results in two great reduction of initial permeability, while more than 80% diluent results in the compressive strength of the consolidated sand being too low, if consolidation takes place at all.

Once the wettability conditions of a given producing sand have been established for one well in a given field, they generally hold true for the remainder of the wells in that field. Separate testing of sand samples from each field well is generally not necessary.

Where the sand to be consolidated has streaks of varying permeability, a granular filler such as ground nut shells with particle sizes extending through the range from about 80 to 200 mesh, in a concentration of about .85 to 1.0 pound per gallon of diluent and plastic, controls the penetration by partially plugging off the more permeable sand sections and directing the remaining plastic to the less permeable zones.

While I have thus described my invention with reference to the foregoing specific examples of its use, it is to be understood that other and further modifications and variations of the invention will be apparent to those skilled in the art. The scope of the invention therefore, should not be considered as limited by the foregoing description and examples, but is properly to be ascertained from the appended claims.

I claim:

1. A method of producing a well which includes the step of consolidating the loose sands of a fluid-producing formation penetrated by said well, said consolidating step comprising obtaining samples of said sand, applying to one sample a mixture of a resin-forming liquid and oil acting as a diluent therein, to determine whether the resin of said mixture will combine with and coat the particles of sand and the diluent will occupy the interstices of the sample or vice-versa, applying to a second sample a mixture of said resin-forming liquid and water acting as a diluent therein, to determine whether the resin of said mixture will combine with and coat the particles of said sand and the diluent will occupy the interstices between the particles or vice-versa, injecting into said formation that mixture of resin-forming liquid and diluent which combines with the sand particles so that the resin coats the particles and the diluent occupies the interstices between the particles, whereby the particles of sand in said formation are wetted only by said resin-forming liquid, maintaining said mixture in place in said formation while said resin-forming liquid solidifies, and producing fluids from said formation into said well to remove said diluent and leave the formation surrounding said well consolidated and permeable.

2. A method as in claim 1 wherein said mixture is between 20 percent and 80 percent by volume resin-forming liquid, and the balance is diluent.

3. A method as in claim 1 wherein said mixture is between 25 percent and 50 percent by volume resin-forming liquid, and the balance is diluent.

4. A method as in claim 1 wherein said resin-forming liquid is a phenol-aldehyde partial condensation product and a catalyst to induce setting of said resin-forming liquid at formation temperatures.

References Cited in the file of this patent

UNITED STATES PATENTS

2,573,690	Cardwell	Nov. 6, 1951
2,674,322	Cardwell	Apr. 6, 1954

OTHER REFERENCES

The Industrial Chemist, December 1949, pages 566–572.