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SAND CONSOLIDATION METHOD

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This invention is primarily directed to a method for consolidating the sands of loose or incompetent formations penetrated by a borehole. In its more particular aspects, this invention concerns a method for consolidating the sands of subsurface formations by injecting plastics into the formations.

In producing fluids from subsurface formations, sand is produced along with the formation fluids from loosely consolidated formations. Because production of sand with its attendant accumulation in the well bore or movement to the surface is undesired, various sand control measures have been used to inhibit or prevent sand particles from moving into the well bore. One type sand control measure is the use of plastics which bind the sand particles together while permitting flow of well fluids therethrough.

Particularly good consolidating plastics of this type make use of the resin-forming properties of the reaction between a water soluble aldehyde and a low molecular weight hydroxy aryl compound catalyzed by an alkaline or acid catalyst. When these compounds are injected into a sand formation, a resin forms which cements the particles of the formation together. Although, any water soluble aldehyde may be used, formaldehyde, acetaldehyde, propionaldehyde, or mixtures thereof are preferred. The low molecular weight hydroxy aryl compound may include phenol, cresol, beta naphthol, resorcinol, or cresylic acid, or mixtures thereof; for low temperature formations xylanol, especially 1,3,5-xylanol, is preferred. Suitable alkaline catalysts which may be used include guanidine salts, such as guanidine carbonate and amino-guanidine bicarbonate; alkali metal hydroxides and carbonates, such as sodium hydroxide or sodium carbonate; aliphatic amines, such as ethyl amine and triethyl amine; aromatic amines, such as aniline; and aliphatic diamines, such as ethylene diamine. Suitable acidic catalysts which may be used include acidic salts, such as stannous chloride or magnesium chloride; mineral acids, such as hydrochloric acid or sulfuric acid; acid anhydrides, such as maleic anhydride; aromatic acids, such as picric acid or benzene sulfonic acid or sulfanilic acid; and polynuclear aromatic acids or acid salts, such as alpha naphthylamine sulfonic acid or sodium-1-naphthylamine-3,6,8-trisulfonate.

Resin-forming compositions employed for consolidating sands in oil producing formations are only slightly miscible with either oil or water. Fluid flow studies show that in order for one liquid to efficiently displace another liquid from the surface of a sand grain, the two liquids should be mutually miscible. Since one desired requisite for successful sand consolidation with a plastic mixture is that the sand grains be wetter by the plastic, the liquid in contact with the sand grains should be replaced prior to the injection of the consolidating plastic by another liquid with which the plastic mixture is miscible.

In the case of water-wet sands, the formation may be pretreated by replacing the water normally in contact with the sand grains with another liquid with which the plastic is miscible, prior to the injection of the resin-forming mixture.

Thus, by injecting a polar organic compound miscible with both the connate water and the following plastic ingredients into the formation to displace the connate

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water prior to injection of the plastic ingredients, an improved plastic consolidation is achieved. Formalin, acetone, methylamine, methanol, or other alcohol, ketone or solution of aldehydes or amines are examples of polar organic compounds that may be used in this pretreatment to displace the connate water and to be displaced by the plastic solution. This method of sand consolidation is disclosed and claimed in U.S. patent application Serial No. 759,442, entitled "Method for Consolidation of Sand," by R. E. Williams et al., filed September 8, 1958, and now abandoned.

In the case of oil-wet sands in which the polar organic compound does not displace the oil from the sand surface, a surface-active agent may be added to the pretreating polar organic compound. This method may be employed advantageously even in the consolidation of predominantly water-wet sands or "mixed wettability" sands. The latter sands are sands having areas of water-wetness and areas of oil-wetness. The surface-active agent has the property of being absorbed on the sand surface thereby displacing the oil and rendering the surface wet by the polar organic compound which is subsequently displaced by the plastic-forming ingredients. Surface-active agents suitable for inclusion in the polar organic compound to render sand surfaces "plastic wet" may be anionic agents, such as alkyl, aryl, or alkyl aryl sulfonates or sulfates, sulfated or sulfonated amides, ethers or esters; cationic agents, such as amine salts or quaternary ammonium chlorides; or non-ionic agents such as esters, ethers or ether-esters of the natural fats and oils; or the alkyl phenols. Polyoxyethylene sorbitan monolaurate, polyoxyethylene sorbitan monopalmitate, polyoxyethylene sorbitan monooleate, oxyalkylated amylphenol, alkyl aryl polyether alcohol, and polyoxyethylene ether are examples of surface-active agents which may be used.

With regard to the plastic mixture, itself, heretofore all of the reactive ingredients of the plastic mixture have been mixed at the surface and then injected into the formation. This procedure for the formation of sand consolidation plastics has disadvantages. For example, base catalyzed plastics must be refrigerated during mixing to prevent premature separation and hardening in the tanks or tubing; acid catalyzed plastics may not be used for low temperature formations because of the danger of slight deviation in component composition causing premature separation; and neither the base catalyzed nor the acid catalyzed plastics can be used to consolidate unusually long producing intervals because the prolonged injection time required to consolidate such intervals would cause separation of the plastic mixture before placement could be completed.

The present invention overcomes these disadvantages by providing for injection of the reactive ingredients of the plastic mixture in two parts. The first part injected includes all the reactants except the low molecular weight hydroxy aryl compound. The second part injected includes the low molecular weight hydroxy aryl compound dissolved in oil. The second part of the plastic mixture is substantially immiscible with the first part of the mixture. Therefore, as the second part passes through the formation sand following injection thereof, a portion of the first part remains on the sand surfaces as connate liquid and extracts a fraction of the low molecular weight hydroxy aryl compound from the second part. The concentration of the hydroxy aryl compound in the second injected part is so regulated that extraction of the hydroxy aryl compound will cease when the first part injected has dissolved the proper amount of the hydroxy aryl compound. The proper concentration of the hydroxy aryl compound in the sec-

ond part of the mixture injected is experimentally determinable. This concentration is dependent on the volume of solution it is desired to use and it is the amount that will cause the sand to be consolidated throughout the treated portion. An excessive concentration of hydroxy aryl compound in the diesel oil causes the sand nearest the well bore to be inadequately consolidated. Conversely, too low a concentration will consolidate too little sand to withstand the pressure differential caused when the well is produced.

The invention of the two part injection of the reactive ingredients of the plastic mixture may be employed in conjunction with the preflushing procedure described supra. When the preflush procedure is used, the preflush containing water-wetting agents dissolved in formalin is miscibly displaced by the first part of the plastic mixture injected.

The practice of the invention including the manner in which the proper concentration of cresol in the oil solution is determined is illustrated by the following experimental procedure:

Glass tubes 1½ inches in diameter and 12 inches long equipped with suitable flow control heads were packed with formation sand from an oil well. The packed tubes were saturated with 5 percent salt water and flooded with oil to simulate sand in place in an oil well. The tubes then were treated by injecting a preflush solution of a surfactant dissolved in formalin. The preflush solution was miscibly displaced with the first part of the reactive ingredients of the plastic mixture which comprised 400 ml. formalin, 70 gms. guanidine carbonate and 15 gms. sodium hydroxide. Then the second part of the reactive ingredients comprising cresol in diesel oil was injected to displace immiscibly the first portion of the reactive ingredients. The tubes then were heated at 145° F. for 24 hrs. to allow the plastic forming reaction to occur.

The results of a series of experiments conducted in accordance with this procedure, in which the concentration of cresol in oil as well as the volume of the cresol-oil solution used were varied, are shown in the following table:

Table

	Concentration of Cresol in Oil, Percent by Wt.	Quantity of Cresol-in-Oil Solution, ml.	Consolidation Obtained
I-----	10	400	Weak consolidation.
II-----	6	500	Inflow end weak, center consolidated.
III-----	4	300	4 inches consolidated at inflow end.
IV-----	4	1,240	Inflow end weak, remainder consolidated.
V-----	3	200	2.5 inches consolidated at inflow end.
VI-----	3	900	Good consolidation throughout tube.
VII-----	3	3,000	Good consolidation.
VIII-----	2	4,000	Good consolidation throughout tube.
IX-----	2	20,000	Do.

As seen by the data of Experiment I, when the second part or oil solution injected contained 10 percent cresol, the use of 400 cc. of the oil solution to displace the first solution injected gave a weak consolidation. This indicates that a 10 percent cresol concentration approaches a maximum usable amount.

The data of Experiment II show that decreasing the cresol concentration in the oil solution and increasing the volume of oil solution from that of Experiment I resulted in center consolidation although the inflow end remained weak.

Comparisons of Experiments III with IV and of Experiments V with VI show that when intermediate concentrations of cresol in oil were used with small, inter-

mediate, and large volumes of oil solution, consolidation of limited amounts of sand in the inflow end was obtained with the small volumes (Experiments III and V) and weakening of the inflow end was obtained when a large volume was used (Experiment IV) or complete consolidation was obtained when an intermediate volume of oil-cresol solution was used (Experiment VI).

The data of Experiments VII, VIII, and IX show that good consolidation can be attained at smaller concentrations of 2 to 3 percent of cresol even though large volumes of the oil-cresol solution are used.

The cores taken from the successful consolidation showed good permeability and compressive strengths; for example, cores taken from the successful consolidation of Experiment VI had permeabilities greater than 3 darcies and compressive strengths greater than 535 p.s.i. and less than 735 p.s.i.

Alternatively, the volume and concentration of the hydroxy aryl compound in oil may be obtained experimentally as follows:

A formalin solution containing catalyst with sufficient cresol to give a resin yield of 20 to 40 percent by volume of the formalin solution (which solution is in the range of 5 parts to 1 part formalin to 1 part of the cresol) is prepared. A standard volume of the prepared formalin solution then is equilibrated with solutions of oil containing varying concentrations of cresol until the concentration of cresol is found in which none of the cresol is extracted from the oil or from the formalin solution. The concentration of cresol in oil is adjusted such in this manner so that the desired relative volumes of the first and second parts of the consolidating solutions to be used in a well will give from 20 to 40 percent resin.

For field applications the cresol concentration may be preferably in the range of 1 to 10 percent and the volume of solution may be preferably 0.1 to 5 barrels/ft.

Thus, the invention provides a method of sand consolidation that is economical, rapid acting, generally applicable to various types of formations, and that overcomes various disadvantages inherent in other sand consolidating procedures.

Having fully described the nature, objects, and operation of our invention, we claim:

1. A method for consolidating the sands of an incompetent, water wet, formation comprising injecting into said formation a resin-forming mixture including a water-soluble aldehyde, a catalyst, a low molecular weight hydroxy aryl compound, and oil in two parts, the first part injected which is free of said low molecular weight hydroxy aryl compound comprising said water-soluble aldehyde and catalyst and the second part injected comprising said low molecular weight hydroxy aryl compound and oil, the first part injected miscibly displacing connate liquid wetting the sand grains of the formation and a portion of the first part remaining on the surfaces of the sand grains in the connate position, and the second part injected immiscibly partially displacing the first part injected, said portion of the first part injected remaining on the sand grain surfaces in the connate position extracting a fraction of the low molecular weight hydroxy aryl compound from the second part injected to form the resin and thereby consolidate the sands of the formation, the relative volumes of said aldehyde, catalyst, and hydroxy aryl compound being selected so as to yield from 20% to 40% resin.

2. A method as recited in claim 1 including employing an alkaline catalyst as said catalyst.

3. A method as recited in claim 2 including employing guanidine carbonate and sodium hydroxide as said alkaline catalyst.

4. A method as recited in claim 3 including employing cresol as said hydroxy aryl compound and formalin as said aldehyde.

5. A method as recited in claim 4 including injecting a polar organic compound and a surface active agent

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into said formation prior to injection of said first part of said resin-forming mixture.

6. A method as recited in claim 5 including employing cresol in amounts in the range of 1 to 10% by weight of said second part injected and employing 0.1 to 5 barrels of said second part injected per foot of sand section opened to the well bore.

7. A method as recited in claim 1 including employing an acidic catalyst as said catalyst.

8. A method as recited in claim 7 including employing stannous chloride as said acidic catalyst.

9. A method as recited in claim 8 including employing cresol as said hydroxy aryl compound and formalin as said aldehyde.

10. A method as recited in claim 9 including injecting a polar organic compound and a surface active agent into said formation prior to injection of said first part of said resin forming mixture.

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11. A method as recited in claim 10 including employing cresol in the range of 1 to 10% by weight of said second part injected and employing 0.1 to 5 barrels of said second part injected per foot of sand section opened to the well bore.

References Cited in the file of this patent

UNITED STATES PATENTS

2,143,990	Loomis	Jan. 17, 1939
2,246,725	Garrison	June 24, 1941
2,378,817	Wrightsmen et al.	June 19, 1945
2,457,160	Kurtz et al.	Dec. 28, 1948
2,476,015	Wrightsmen	July 12, 1949
2,612,954	Hamilton	Oct. 7, 1952
2,714,929	Nowak et al.	Aug. 9, 1955
3,047,067	Williams et al.	July 31, 1962