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[54] **METHOD FOR INJECTING FLUIDS INTO UNDERGROUND FORMATIONS HAVING DIFFERING PERMEABILITIES**
4 Claims, 1 Drawing Fig.

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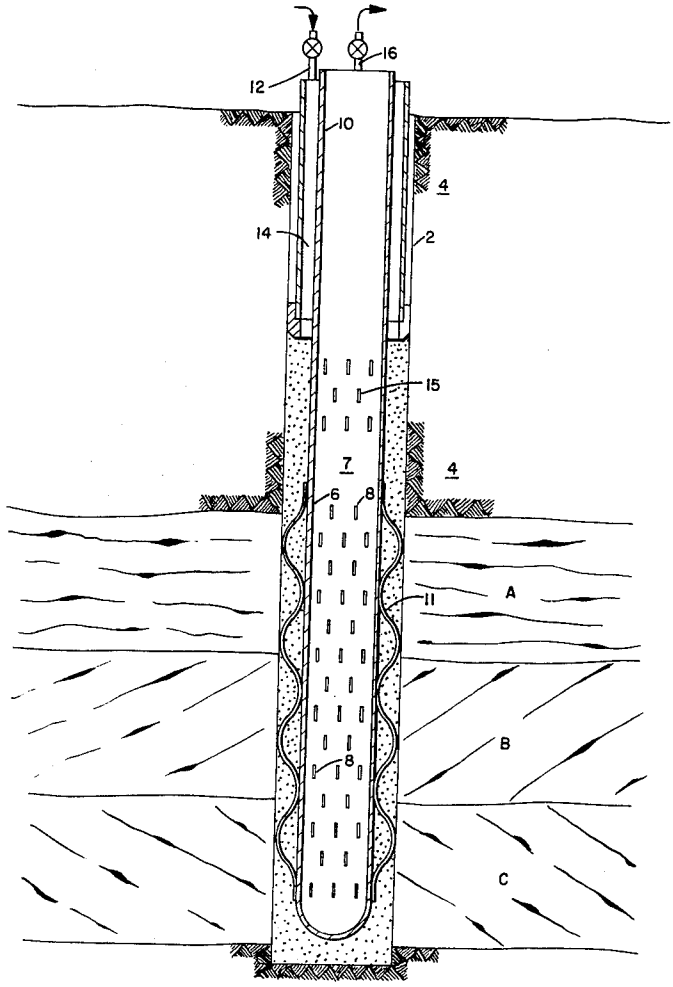
[56] **References Cited**

UNITED STATES PATENTS

2,140,072	12/1938	Chenault	166/51
2,365,428	12/1944	Muskat	166/268
2,597,554	5/1952	West	166/278
2,677,428	5/1954	Clark	166/278
2,823,753	2/1958	Henderson et al.	166/276X
2,885,004	5/1959	Perry	166/271X
2,986,538	5/1961	Nesbitt et al.	166/276X

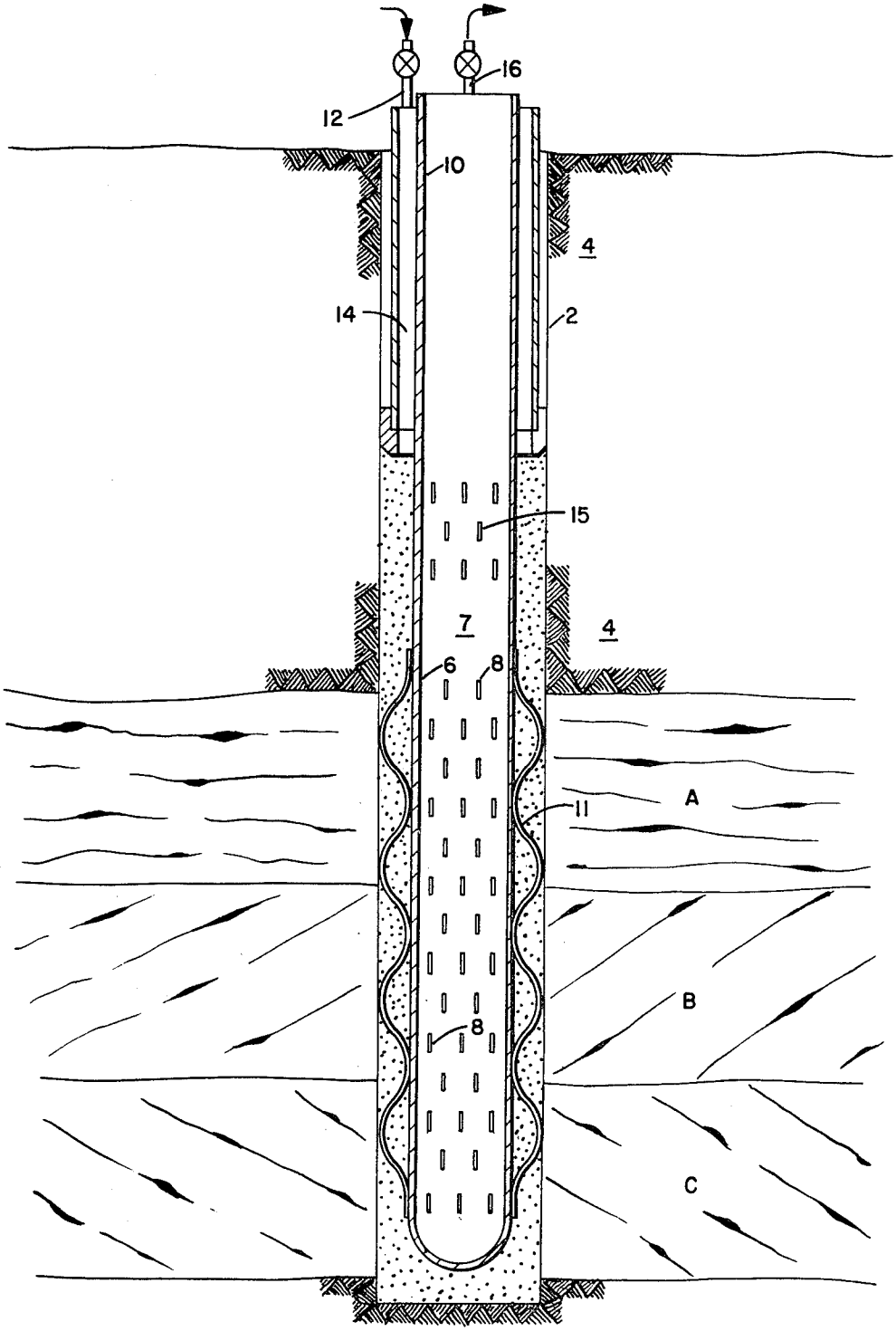
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ABSTRACT: A method of simultaneously injecting fluids into adjacent sections of subterranean formations of diverse permeability. A slotted sleeve or mesh cylinder is positioned in the wellbore opposite the formation and sand providing a low permeability pack is deposited in the annulus between the wellbore wall and the sleeve. Sand size is selected to provide a sand pack of permeability less than the lowest permeability of the formation. The sand pack may be consolidated with a resin. Fluid is injected down the interior of the sleeve, through apertures in the sleeve, through the low permeability, sand-filled annulus into the formation. Flow of fluids into the formation is more evenly distributed over the length of the wellbore section.



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3,580,338



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METHOD FOR INJECTING FLUIDS INTO UNDERGROUND FORMATIONS HAVING DIFFERING PERMEABILITIES

FIELD OF THE INVENTION

This invention relates to the injection of fluids into underground formations. More particularly, it is concerned with controlling the rate of fluid injection into underground formations which are penetrated by oil, gas and water wells and which have wide variances in permeability in adjacent sections of the formation.

PRIOR ART

It is often desirable to inject fluids, particularly liquids, into an underground formation through existing oil, gas or water wells which penetrate the formation. Such practices include the injection of acids and paraffin solvents to improve well productivity of fluids. In waterflooding operations it is also desirable to inject water at a nearly consistent rate throughout the vertical section of the formation. More recently a technique for consolidating loose or friable underground formations in the region around the wellbore has been developed. The technique includes the step of injecting into the formation around the wellbore a consolidating resinous material in a carrier liquid. The resinous material polymerizes and sets, thus bonding the grains of the friable formation into a rigid but permeable mass. One such method of using resinous materials to consolidate friable sands is discussed in U.S. Pat. No. 3,282,338.

One difficulty in injecting fluids into underground formations is that in a horizontal direction the permeability of the formation to the injected fluid often is not uniform throughout the depth of the formation penetrated by the wellbore. Consequently, most of the injected fluids will flow laterally from the wellbore into the more permeable sections and little, if any, fluid will flow into the less permeable sections. As a result, treatments, such as a sand consolidation treatment, will be a failure. Waterflood projects will have limited efficiency.

One method of combating the problem of permeability variations in a formation is to isolate sections of the wellbore by means of packers and to inject fluid into the formation only through those isolated sections. By repeating this operation at different depths fluid can be injected into the formation over the entire length of the wellbore. This type of procedure obviously is expensive and time consuming. Difficulties in locating the packers precisely opposite a given section of the formation are also a problem.

OBJECTS OF THE INVENTION

It is therefore an object of my invention to provide an improved method of injecting fluids into an underground formation penetrated by a wellbore. Another object of my invention is to provide a method of injecting fluid into a subterranean formation having sections of a wide variance in permeability whereby a uniform vertical distribution of fluid is obtained in the formation laterally around the wellbore. Still another object of my invention is to provide a method whereby the entire vertical section of a formation penetrated by a wellbore may be injected with fluid pumped into the wellbore.

SUMMARY OF THE INVENTION

Briefly stated, my invention comprises placing a slotted or perforated sleeve or cylindrical screen in a wellbore extending the length of the wellbore section into which fluids are to be injected and depositing between the exterior of the sleeve or screen and the wall of the wellbore a mass of particulate matter of low permeability. Fluid to be injected into the formation is introduced into the interior of the slotted sleeve or screen and then injected through the slotted sleeve or screen, through the low permeability mass in the annulus between the screen and wellbore wall and into the formation. The result is a more even distribution of injected fluid throughout the vertical depth of the formation around the wellbore in a direction extending laterally from the wellbore.

BRIEF DESCRIPTION OF THE DRAWING

The accompanying drawing depicts in vertical cross section the application of my method to an underground formation having three adjacent Sections A, B and C of diverse permeability into which it is desired to inject a fluid, for example a plastic consolidating agent or waterflood water.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now more specifically to the drawing, reference numeral **2** denotes generally a wellbore extending through the overlying formation through Sections A, B and C, which are to be treated according to the method of my invention. For purposes of description, it will be assumed that Sections A, B and C are to be injected with a consolidating resinous material and that they have widely different permeabilities. As noted previously, however, my invention is not to be deemed to be limited to the injection of consolidating materials into underground formations but is equally applicable to other operations such as the injection of water for waterflooding and the injection of acids and paraffin solvents.

As a first step in my invention, a cylindrical sleeve **6** with a plurality of slots **8** penetrating its wall is positioned in the wellbore opposite the section of formation to be injected. A rigid sleeve of mesh screens would function equally well. Either should, however, have a closed bottom.

To aid in determining when the annulus section opposite the section of formation to be treated is completely filled with sand the slotted sleeve **6** has a portion that is blank or unslotted **7** above which is a section **15** which is slotted. If a mesh-type sleeve is used, there should be a solid section above which there is a small section of screen. In either instance, the slotted sleeve or screen is positioned in the wellbore so that the bottom of the blank or unslotted section is just at or above the top of the section of formation to be treated. Centralizers **11** are attached to the sleeve at intervals sufficient to position the sleeve in the center of the wellbore. The sleeve **6** is suspended from tubing generally indicated at **10**.

Next, a slurry of particulate matter, such as sand, suspended in a carrying liquid (for example, oil) is injected through conduit **12** into the annulus **14** between the wellbore wall and the slotted sleeve or screen. The dimensions of the slots of mesh openings in the sleeve or screen are selected to be less than the dimensions of the sand so that as the liquid suspension of sand is pumped into the annulus the sand is retained behind the wall of the slotted sleeve or screen **6** and the liquid carrier flows back up through the interior of the liner and is removed through valved conduit **16**.

The particulate matter (sand) suspended in the carrier liquid is selected according to particle size to provide a predetermined permeability when the sand is packed in place between the wall of the wellbore and the exterior of the sleeve. Ordinarily, the permeability of the sand pack should be equal to or preferably substantially less than the lowest permeability of any section of formation exposed to the sand pack.

When sufficient sand has been deposited or packed between the sleeve or screen **6** and the wall of the wellbore **2** to a level above the uppermost formation to be treated, injection of sand-oil slurry is discontinued.

The time at which sufficient sand or other particulate matter has been deposited is indicated at the surface by a sudden upsurge in the injection pressure. When the surge occurs it indicates that sand has filled the annulus up to and including the topmost slotted section of the liner. By providing this topmost slotted section above an unslotted section, the operator can be sure that the annulus is filled with sand throughout the vertical sections opposite the formation to be treated. This sand pack in the annulus between the liner and wellbore wall will have a permeability lower than the permeability of any section of the formation to be treated. In the final step the

treating fluid, liquid, gas or waterflood water, is now injected down the interior of the liner through the sand pack. It is distributed uniformly over the face of the wellbore for the entire vertical section of formations surrounding the wellbore. As a result, the injected fluid flows into the less permeable sections of the formation as well as the more permeable sections. The more permeable sections do not receive injected fluid at a rate faster than the impermeable sections.

In using this final step to consolidate friable formations, for example a solution of the consolidating resin is injected through conduit **16** down the interior of liner **6**, through slots **8**, and then through the sand pack and into Sections A, B and C. When sufficient consolidating resin has been injected, injection is discontinued, and sufficient time for the resin to set is allowed to elapse.

When injection of water or other treatment of the formation is complete, the liner **6** is removed, and the well is cleaned of the sand by conventional techniques, such as wash over or redrilling; or the sand may be removed by opening the valve in conduit **12** and circulating liquid down the liner, through the slots, and then up the annulus and through conduit **12**. This latter method of removing the sand from the annulus will work only if the sand in the annulus has not also been consolidated.

In a variation of this method, it may be desired to consolidate the sand pack created between the liner and wellbore wall. This can be done in at least two ways. In one variation, a solution of consolidating resinous material which can be catalyzed slowly to a rigid plastic is mixed in the carrier fluid with a suitable quantity of a catalyzing agent. Sand is added to the mixture and the liquid suspension of sand containing the plastic and catalyzing agent is then pumped into the annulus. The sand as it is screened out in the annulus is coated with sufficient resin and will set into a rigid permeable mass under the action of the catalyzing agent. This is a preferred method of consolidating the sand pack. In a less preferred method, the catalyzing agent is omitted from the sand-liquid mixture and injected in a carrier down the annulus into the sand pack after it has been put in place. This is less preferred, however, since it is not certain all of the sand pack will be contacted by the catalyzing agent.

Suitable resin consolidating materials include in general any thermosetting resin. Specific examples are the polyepoxides; hydroxy aryl-aldehyde, such as pheno-formaldehyde; urea-formaldehyde; melamine-formaldehyde; acrylic-type prepared from methyl methacrylate, ethylacrylate, n-butyl methacrylate, isobutyl methacrylate, ethyl methacrylate and similar esters, alone or in combination with other monomers; vinyl polymers prepared from vinyl chloride, vinyl acetate, polyvinyl alcohol, polyvinyl acetal, polyvinyl butyral, polyvinyl formal, vinylidene chloride and the like; allyl resins, such as allyl diglycol carbonate; glyceryl phthalate and similar alkyl resins; polyester resins prepared by the copolymerization of a dihydride alcohol, such as ethylene glycol, an unsaturated dibasic acid, such as fumaric acid and an unsaturated monomer, such as styrene or the like; polyurethane derived from polyisocyanates, such as toluene diisocyanate and polyols, including glycols, polyesters and polyethers; silicones produced by the hydrolysis and condensation of organosilanehalide intermediates; styrene polymer and copolymer. Formulation of each of these resins is well known in the art.

As for curing agents, activators or catalysts, a number are known which harden unset polyepoxide resins. These include amines, dibasic acids and acid anhydrides. The preferred hardening agents are the amines, especially those having a plurality of amino hydrogen groups. Included are aliphatic, cycloaliphatic, aromatic or heterocyclic polyamines, such as diethylene triamine, ethylene diamine, triethylene tetramine, dimethylamino propylamine, diethylamino propylamine, piperidine, methane diamine, triethyl amine, benzyl dimethylamine, dimethylamino methyl phenol, tridimethyl amino methyl phenol, α-methylbenzyl dimethylamine, metaxylene diamine, 4,4'-dimethylene dianiline, pyridine, and the like. Mixtures of various amines may be preferred. The amines or other curing agent react rather slowly to convert the polyepoxides to an insoluble form. The particular curing agent and concentration thereof can easily be determined by a knowledge of temperature conditions and available working time, i.e., length of time between adding the curing agent and final positioning of the resin-containing mixture downhole. Generally, the curing agent is added just prior to pumping the slurry into the well.

EXAMPLE

The section of formation to be treated is one in which water is being injected as part of a waterflooding project. The formation is penetrated by a water injection well having a 12-inch wellbore diameter from a depth of 4,619 feet to a depth of 4,893 feet and has some streaks with a permeability as low as 100 millidarcys. Using the accompanying figure as a diagram, Section A has an average permeability of 5,000 millidarcys, Section B has an average permeability of 1,000 millidarcys and Section C an average permeability of 500 millidarcys. Consequently, all injected water is lost to Sections A and B. It is desired to inject more water into Sections B and C. A perforated liner having an exterior diameter of 7½ inches is positioned at a depth between 4,614 and 4,898 feet opposite the formation. The liner is perforated with holes having a diameter of 0.005 inch. The minimum distance between the exterior of the perforated liner and the wellbore wall is about 2 inches. It is desired to place a consolidated sand pack in the annulus between the perforated liner and the wellbore wall. Accordingly, sand is suspended in an oil of 15°API gravity in the ratio of 15 pounds per gallon of oil and 1.5 pounds of phenol-formaldehyde resin and 0.15 pound of catalyst containing 15 percent sodium hydroxide as the active ingredient are mixed also with each gallon of sand-oil suspension. This sand-oil-resin-catalyst mixture is pumped into the annulus of the wellbore at a rate of 21 gallons per minute. The filtered liquid is flowed back up the interior of the liner and removed. Injection of the mixture into the wellbore annulus is continued until the annulus opposite the slotted section of tubing is filled with sand, as indicated by a pressure surge at the surface injection pump. The sand used in this operation has a 10 percent particle size of 0.0029 inch and, when consolidated with a phenol-formaldehyde resin such as that used in this operation, has an average permeability of 40 millidarcys. The well is then shut in for a period of 24 hours to allow the sand pack in the wellbore annulus to set and cure. The well is then opened, and water injection is resumed. Water is injected at a rate of 2,500 barrels per day. Previous attempts to waterflood the formation surrounding the wellbore had resulted in all water flowing into the high permeability Section A. The well now takes less injection water but all sections of the formation are now being injected with water. The fact that all sections are being injected with water is demonstrated by tests in neighboring oil recovery wells showing that oil is being displaced into the wellbore of each well from the less permeable sections of the formation.

Having thus described the invention,

I claim:

1. A method of simultaneously injecting fluids into a plurality of sections of a subterranean formation having differing permeabilities penetrated by a well bore comprising:

a. positioning a perforated sleeve opposite said sections to be injected;

b. mixing a suspension of particulate matter comprising solid particles having a diameter greater than any diametric dimension of a perforation in the perforated sleeve, a liquid carrier, and resinous adhesive forming substance;

c. injecting the suspension into the annulus between the perforated sleeve and the wall of the well bore;

d. flowing the liquid carrier through the perforations in the perforated sleeve thereby filtering out the particles into the annulus between the perforated sleeve and the wall of the well bore;

e. terminating the flowing of (d) when the annulus has been filled to a desired height;

f. converting the resinous adhesive forming substance into a polymeric adhesive which adheres particles of said particulate matter into a consolidated mass having a predetermined permeability which is not greater than the lowest permeability of any section of the formation; and

g. injecting a fluid from the interior of said sleeve through the consolidated permeable mass of adhered solid particulate matter into the sections of the formation.

2. The method of claim **1** wherein the particulate matter of (b) is sand.

3. The method of claim **1** wherein:

h. the particulate matter of (b) is sand;

i. the liquid carrier of (b) is a light oil; and

j. the resinous adhesive forming substance of (b) is a phenol-formaldehyde resin and a basic activator.

4. The method of claim **3** wherein the injected fluid of (g) comprises water.