

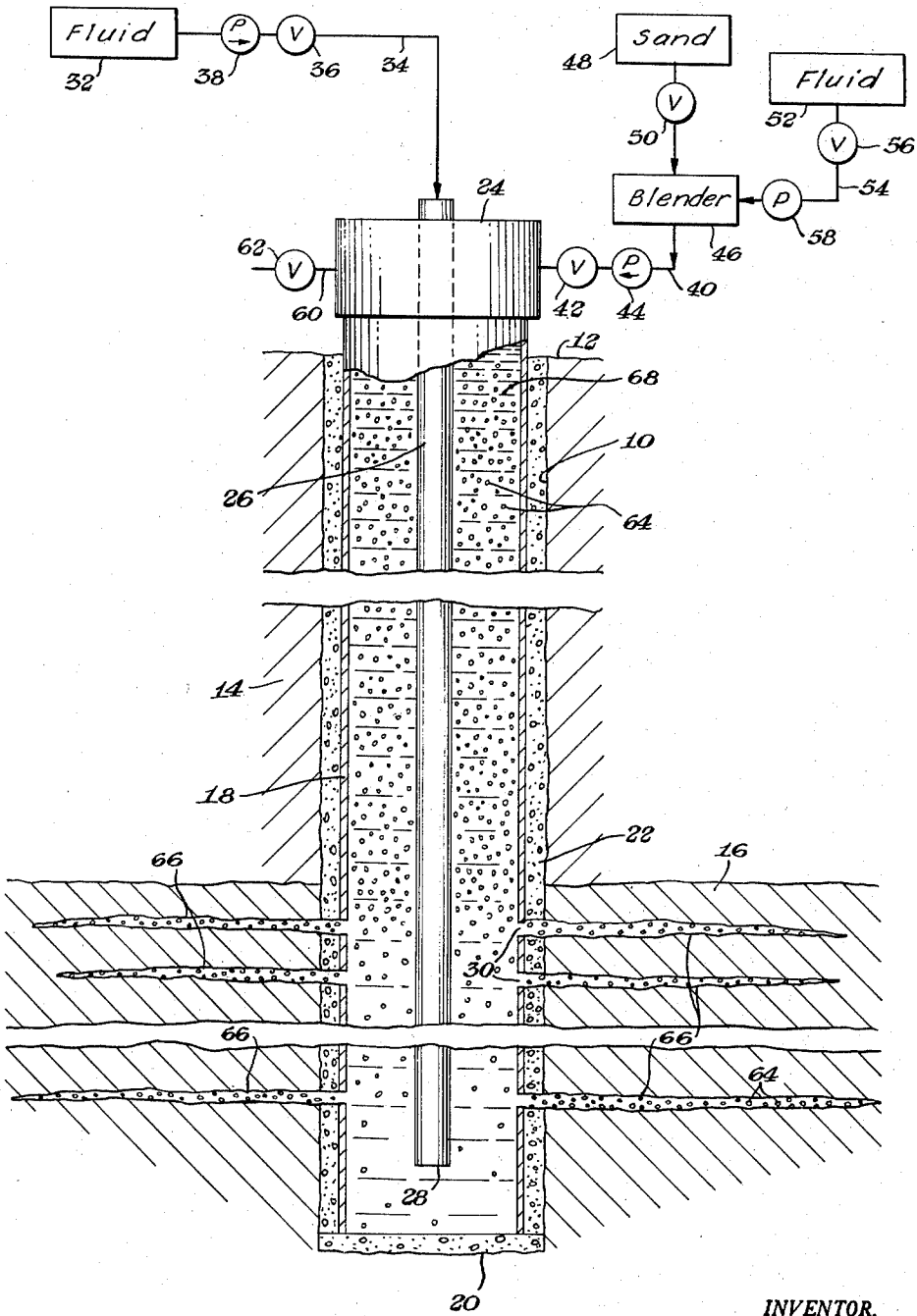
June 2, 1959

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2,888,988

METHOD OF TREATING EARTH FORMATIONS

Filed March 19, 1957



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2,888,988

METHOD OF TREATING EARTH FORMATIONS

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Application March 19, 1957, Serial No. 647,062

11 Claims. (Cl. 166—15)

The invention relates to methods of treating fluid-bearing earth formations into which a well is drilled so as to obtain from or dispose thereinto a fluid with greater facility. The invention more particularly concerns the treatment of a petroleum fluid-bearing formation into which a well is drilled so as to facilitate flow of oil or gas to the well from the formation.

One of the methods currently in use for increasing the fluid permeability and the productivity of earth formations, particularly those in which oil and gas wells are drilled, consists in making an injection of a particulated solid material, such as sand, into the producing formation to form masses therein of high fluid permeability. In making such injections, the sand, or other particulated solid material, is suspended in a fluid vehicle or carrying agent, such as an oil, for example. The suspension is injected into the producing formation by pumping it through the well from a supply maintained at the head of the well. But attempts to make such injections are not always successful because the particulated solid material tends to filter out of the vehicle at the face of the earth formation in the well hole instead of passing into the earth formation with the fluid vehicle. When the particulated material filters out, such a condition is commonly referred to as a "screen-out."

Accordingly, it is an object of the invention to provide an improved method of injecting a particulated solid material into an earth formation penetrated by a well bore whereby the risk of the particulated solid material filtering out of the vehicle in the well hole rather than entering the earth formation is reduced, if not eliminated, and the injection can be made usually without encountering excessive injection pressures.

Another object of this invention is to provide a method of changing the concentration of particulated materials with respect to the carrying agent at any time at the point along the well bore where the injected materials enter the earth formation.

In carrying out the invention, which may be practiced in a well provided with the usual casing and a tubing string extending from the surface to at least near the formation to be treated, the mixture or slurry of particulated material and carrying fluid is pumped into the well and thence into the formation. As injection of the mixture into the formation proceeds a diluent fluid is also injected into the formation when the conditions of injection of the mixture indicate that a screen out is beginning of particulated material on the face of the formation. The diluent fluid so injected dilutes the mixture of particulated material and carrying agent or fluid about to enter the formation and thereby facilitates its passage thereinto, reducing or eliminating the screen out.

The invention, as well as additional objects and advantages thereof, will best be understood when the following detailed description is read in connection with the accompanying drawing in which the single figure shows, in diagrammatical form, a well which is coupled to apparatus used in practicing this invention.

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Referring to the drawing, a well bore 10 extends from the surface 12 of the earth through an earth formation or formations 14 and into or through an oil bearing formation 16, commonly called a "pay zone." A string of casing 18 extends from the surface 12 of the earth to the bottom 20 of the well bore. The space between the casing 18 and the wall of the well bore 10 is filled with cement 22. In the drawing the cement is shown extending from the bottom 20 of the well bore 10 to the surface 12 of the earth, but in practice the cement sometimes extends only part way between the bottom 20 of the well bore 10 and the surface 12.

The upper end of the casing 18 is capped by a casing head 24 of suitable design through which extends a string of tubing 26 (or casing of smaller diameter than the diameter of the casing 18). The lower end 28 of the tubing 26 is disposed near to the perforations 30 in the well bore wall (and casing 18) which communicate with the oil bearing formation or pay zone 16. The phrase "near to" as applied to the disposition of the lower part of the tubing from which diluent fluid may flow (the end of the tubing could be closed and the tubing walls be perforated) means at, slightly above, or slightly below the casing perforations 30.

A source 32 of diluent fluid, such as lease oil or water, for example, is coupled to the tubing 26 through the line 34, valve 36, and pump 38.

The casing 18 is coupled through a line 40, valve 42 and pump or pumps 44 to a blender 46 in which particulated materials and carrying agent are mixed prior to being pumped into the annulus between the casing 18 and tubing 26. A hopper 48 adapted to contain particulated materials, such as sand or crushed walnut shells, by way of example, is coupled to the blender 46 through a suitable flow control means 50. (It is, of course, recognized that the particulated material may be manually applied to the blender.) A reservoir or tank 52 of carrying agent or fluid such as lease oil, for example, is coupled to the blender 46 through the line 54, valve 56 and pump 58.

In operation the annulus between the tubing 26 and the casing 18, as well as the tubing, are often pumped full of clear carrying agent fluid 68 at the beginning of the formation fracturing treatment, the gas present in the casing and tubing being vented from the casing head 24 through the line 60 with the valve 62 open. When the tubing 26 and annulus are filled with carrying agent or other suitable liquid, the valve 62 is closed. Usually more clear carrying agent is then pumped into the annulus to increase the hydrostatic pressure and break down the earth formation (pay zone) adjacent to the perforations before particulated materials are blended into the carrying agent. The above described precautionary step of breaking down the earth formation before injecting into the annulus any blend of carrying agent and particulated materials is not essential, but avoids the possibility of a screen-out which would occur if blended carrying agent and particulated materials were initially injected and the formation 16 didn't break down and permit the fracturing slurry to enter the formation. Once a screenout occurs, considerable time and effort is required to flush from the well bore the screened-out particulated material before the formation fracturing treatment may be resumed or the well placed on production again.

The breakdown of the formation to be fractured is normally indicated at the earth's surface by a rather sudden drop in the pressure required to inject the carrying agent into the formation. The start of a screen-out, however, is usually indicated by a pressure build-up after the formation breakdown occurs and as the slurry of carrying agent and particulated materials is being injected into the formation being fractured.

Following the breakdown of the formation 16 to be fractured, a slurry or blend of carrying agent and particulated materials 64 is pumped through the perforations 30 and into the fractures 66 to expand and extend the fractures 66 and to carry particulated materials 64 into and through the fractures 66 to act as propping agents to hold the fractures 66 open when the fracturing treatment is finished and hydrostatic pressure is released at the well head (permitting the over-burden to settle) and the fractures tend to close.

Occasionally the concentration of particulated material per unit volume of carrying agent exceeds the amount which can, under particular well conditions, be carried into the formation by the carrying agent and the particulated material tends to screen-out on the face of the formation adjacent to the perforations 30. This screening out of the particulated material causes an increase in the pressure required to inject fluid into the formation 16, as previously mentioned. Often the pressure required to inject fluid (during screen-out) exceeds the pressure which the well or treating devices can withstand, and thereby further injection of particulated material is prevented.

When the start of a screen-out is indicated (by a rise in hydrostatic pressure indicated at the earth's surface 12), clear carrying agent is pumped (or pumped at a more rapid rate) through the tubing 28 to quickly dilute the slurry or blend of particulated material and carrying agent, thereby to increase the volume of carrying agent per unit of particulated materials as the slurry is pumped into the formation, carrying the former excess of particulated materials 64 into the formation 16 before a complete screen-out occurs. The carrying agent 68 pumped through the tubing 26 also often helps to clear up a partial screen-out by its washing action as it flows from the tubing to the formation.

Changing the ratio of the amount of particulated materials to the amount of carrying agent at the blender prior to injecting the mixture into the annulus can seldom stop a screen-out from occurring once the pressure buildup is noted because of the time lag in getting the more dilute blend to the perforations from the surface.

When a pressure buildup indicating the start of a screen-out occurs, usually the ratio of particulated materials to carrying agent (or other favorable change in the consistency of the slurry) is also reduced at the blender 46 as well as the pumping of clear carrying agent or diluent through the tubing 26 to immediately lower, at the face of the formation being fractured, the ratio of particulated materials to the fluid carrying the particles into the formation 16. Thus, when the "weaker" slurry injected at the surface 12 does reach the formation 16 the rate of pumping of clear carrying agent through the tubing may be decreased or even stopped until the possible occurrence of another indication of a screen-out. The remainder of the fracturing treatment, following the step or steps (in event of a recurrence of the "symptoms" indicating a "screen-out" is about to occur) to prevent a screen-out, is conventional. That is, a predetermined amount of particulated materials blended into carrying agent is injected into the formation, usually followed by an injection of clear carrying agent (which need not be the same carrying agent as that used in the slurry) through the annulus in an amount sufficient to drive into the formation the slurry of particulated materials and carrying agent which are in the annulus.

The term diluent is understood to mean any liquid capable of diluting the slurry or blend of particulated material and carrying agent. Such liquid may or may not be miscible with the carrying agent and need not be completely free from particulated material. It may be, for example, a more dilute slurry than that being injected as part of the conventional fracturing procedure.

While lease oil has been heretofore mentioned as a carrying agent, many other fluid materials may be used

as carrying agents or diluents. Thickened water, thickened acid, water, acid, emulsions of oil and water or acid, thickened or emulsified crude oil or refined oil are other commonly used carrying agents. Demulsifying or other additive agents may or may not be used in connection with the carrying agents or diluents, depending on the conditions under which a particular well treatment is made.

Any conventional propping agent such as sand, particulated walnut shells, etc. may be used in connection with this invention. Ottawa sand is a preferred sand. The mesh size of the particulated material may be the same as for conventional fracturing treatments.

It should be emphasized that this invention is equally applicable to treatments in which sand and oil (that is, a slurry or blend of particulated materials and carrying agent) are initially pumped into the annulus without any prior injection of clear carrying agent or other liquid to make the initial formation breakdown.

In a typical fracturing operation in accordance with the teachings of this invention, 22,000 pounds of sand (20,000 pounds 20/40 mesh and 2,000 pounds 40/60 mesh sand) were blended with about 14,700 gallons of lease oil. The average sand concentration was thus about 1.5 pounds per gallon of carrying agent. The sand and oil slurry were injected in the annulus between the 7 inch (nominal outer diameter) well casing and the 2 inch (nominal outer diameter) well tubing. Fourteen minutes after the start of the sand-oil injection, the slurry of 14,700 gallons of oil and the sand had been pumped into the casing annulus. Pumping of straight crude oil was then pumped down the annulus (the pumping of the sand-oil slurry and the crude oil was a continuous operation) to flush the sand-oil slurry into the formation 16 to be fractured. After 6 minutes of pumping of crude oil, a pressure rise in the annulus feeding line 40 indicated a screen out was forming. Lease oil was then pumped down the tubing 26 to dilute the concentration of sand 64 being flushed into the formation 16 from the annulus. A drop in injection pressure on the annulus line 40 indicated the screen out had been avoided. About 16,800 gallons of crude oil were pumped down the annulus and the tubing. The well was 6,240 feet deep. No record was kept showing the proportion of the crude oil to the total crude oil pumped which was pumped down the tubing to prevent the screen-out. However, 6 pumper units were used on the treatment, one pumper being connected to inject oil into the tubing 26. Because of friction losses, differences in pumper efficiency and similar varying parameters no exact flow ratio, at the perforations 30, may be made between the tubing flow and annulus flow.

As mentioned previously, the invention may also be practiced by pumping the slurry through the tubing 26 and clear carrying agent through the annulus.

I claim:

1. The method of preventing screen-outs during the injection into an earth formation penetrated by a well bore having casing and tubing disposed concentrically therein of a slurry of particulated material in a fluid carrying agent, comprising, when a rise in injection pressure occurs which indicates the beginning of a screen out, pumping a diluent which is free from particulated material into said well bore at a location which is directly adjacent to the point of entry of said slurry into said formation whereby to dilute the amount of particulated material per unit volume of carrying agent entering said formation.
2. The method according to claim 1, wherein said particulated material is sand.
3. The method according to claim 1, wherein said carrying agent comprises an oil.
4. The method according to claim 1, wherein said carrying agent of the slurry is a fluid different from that of the diluent.
5. The method according to claim 1, wherein said slurry

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is injected through the annulus between said tubing and casing and said diluent which is free of particulated material is pumped through said tubing.

6. The method according to claim 1, wherein said slurry is injected through said tubing and said diluent which is free of particulated materials is injected through the annulus between said tubing and casing.

7. The method of preventing screen-outs during the injection into an earth formation penetrated by a well bore of a slurry of particulated material and fluid carrying agent, comprising, when the beginning of a screen-out is indicated, injecting simultaneously with the injection of said slurry additional fluid carrying agent having less particulated material blended therein than said slurry into said well bore at a location adjacent to the point of entry of said slurry into said formation whereby to dilute the amount of particulated material per unit volume of carrying agent entering said formation.

8. The method according to claim 7, wherein the additional carrying agent injected into said well bore adjacent to the point of entry of said slurry into said forma-

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tion has only a trace of particulated material blended therein.

9. The method of preventing screen-outs during the injection into an earth formation penetrated by a well bore of a slurry of particulated material and fluid carrying agent, comprising, when the beginning of a screen-out is indicated, comprising pumping a diluent into said well bore directly adjacent to the point of entry of said slurry into said formation whereby to dilute the amount of particulated material per unit volume of fluid entering said formation.

10. The method according to claim 9, wherein said diluent and said carrying agent are miscible.

11. The method according to claim 9, wherein said diluent and said carrying agent are immiscible.

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