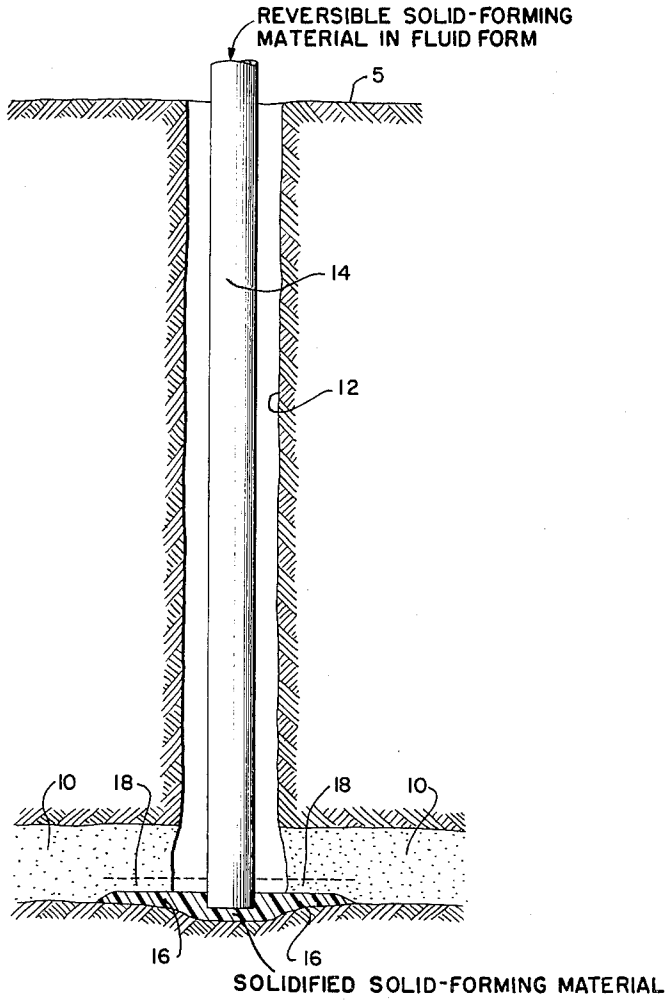
Oct. 2, 1962 R. O. PERRY 3,056,288

METHOD USING A REVERSIBLE SOLID-FORMING MATERIAL TO PROFILE A SUBTERRANEAN FORMATION

Filed July 6, 1959



INVENTOR
ROBERT O. PERRY

BY Adams, Forward & McLean

ATTORNEY

United States Patent Office

3,056,288

Patented Oct. 2, 1962

3,056,288

METHOD USING A REVERSIBLE SOLID-FORMING MATERIAL TO PROFILE A SUBTERRANEAN FORMATION

Robert O. Perry, Tulsa, Okla., assignor, by mesne assignments, to Sinclair Research, Inc., New York, N.Y., a corporation of Delaware

Filed July 6, 1959, Ser. No. 824,914
12 Claims. (Cl. 73—155)

The present invention relates to a method using a reversible solid-forming material to profile a subterranean oil-bearing formation traversed by a production well. More particularly, the present invention is concerned with a method including sealing a portion of the producing formation by injection of a reversible solid-forming material and measuring the amount of fluid produced from the unsealed section of the well bore. Through a progression of determinations of this type a production well profile can be obtained. Knowledge of the "production profile" of subterranean oil-bearing formations is highly desirable for oil production purposes, for instance, to locate water or gas producing zones which can be plugged to provide more efficient recovery of oil.

A formation can be any sedimentary bed or stratum sufficient to be regarded as a unit. Fluids such as petroleum oil, gas or water may be found distributed throughout the formation or only in intervals or zones of the formation. Although a formation may be substantially homogeneous in composition, formations do have random veins which vary in content. Intervals, zones, streaks or veins in the formation alternatively or successively distributed containing various fluids or different ratios of fluids are frequently encountered.

In most petroleum producing areas, the production of petroleum from subterranean oil producing formations is generally accompanied by the production of water or brine that may be present in random streaks, zones or intervals in the formation. Well effluents comprising as much as 90% water and only 10% oil are not uncommon. Pumping the water to the earth's surface and separating it from the oil is not only expensive but in many instances the problem of disposing the waste water is more than one of mere economics. Accordingly, if a production profile of a formation, i.e. information on the vertical distribution of fluids in a formation, traversed by a producing well were available to provide knowledge of the location and amounts of unwanted extraneous materials, e.g. brine, ingressing into a production well, these locations can be sealed and the production of wanted materials, e.g. oil, can be more efficiently accomplished.

An object of the present invention is the provision of a method for determining the "production profile" of a subterranean formation traversed by a well bore. Another object of the present invention is the provision of a method for procuring information as an aid in determining the production profile of a well including the injection of a reversible solid, e.g. resin-forming material into a portion of the producing formation to seal this portion of the formation and measuring the relative amounts of each type of fluid, for instance, one or more, present in the production fluid recovered from the unsealed portion of the formation as an aid in the determination of the production profile of the formation. Another object of the present invention is the provision of a production well

profiling method including the step of injecting a sufficient amount of a reversible solid-forming material into a well bore to selectively seal the lower or bottom portion of a producing formation, measuring the relative amounts of each type of fluid contained in the production fluid recovered from the unsealed upper portion of the formation, removing the resin-forming material from the well; and repeating this operation employing differing amounts of resin-forming material until a progression of such determinations or measurements are obtained; the difference between the relative amounts of liquids from one measurement to another being an indication of the production profile of the well.

Another object of the present invention is the provision of a production well profiling method including the step of injecting a sufficient amount of a reversible solid-forming material into a well bore to selectively seal the lower or bottom portion of a producing formation, measuring the relative amounts of each type of fluid contained in the production fluid recovered from the unsealed upper portion of the formation, injecting a sufficient amount of a solid-forming material into the well bore to selectively seal the lower portion of the unsealed portion of the formation and thus providing another layer of solid-forming material on the previously added solid-forming material, measuring the relative amounts of each type of fluid contained in the production fluid recovered from the unsealed upper portion of the formation, and, if desirable, repeating this operation until a progression of such determinations or measurements is obtained; the difference between the relative amounts of fluids from one measurement to another being an indication of the production profile of the well. In the above objects or in the claims, reference is made to "measuring the amount of each type of fluid" or "the amount of each fluid." It is intended that these terms be interpreted in their usual manner to define production fluids containing only one type of fluid or one fluid, e.g. brine as well as production fluid containing a plurality of fluids, e.g. brine and gas.

The following specific example referring to the drawing will serve to illustrate the present invention but is not to be considered limiting.

The production profile is desired for an oil producing subterranean formation **10** extending from about 356 to 360 feet from the earth's surface **5** and traversed by a well bore **12** which is 6" in diameter. The well is producing liquid including oil and brine at a rate of 4 gallons per minute in a ratio of about 1 part of oil to 10 parts of brine by weight. Aqueous solid-forming material, i.e. guar gum, weighted to be heavier than water and containing 2 weight percent guar gum and 1.5 weight percent calcium chloride (to give the material a recognizable electrical conductivity), is conducted down a string **14** of ½" tubing (centrally disposed in the well bore and extending to a point below the formation), is tracked with a two-conductor cable employed in a stinger arrangement (not shown), is pressured by air to the bottom of the well (360 feet), and displaces material in this area of the well, solidifies, and seals a portion of the formation extending from 359 to 360 feet as shown by **16**. Samples of the liquid produced from the unsealed portion of the well are taken, analyzed and found to contain 5 parts of oil to 5 parts

by weight of water. Production from the unsealed portion of the well is about .87 gallon per minute.

An additional amount of reversible solid-forming material of the above type is placed in the well, solidifies, and seals off the portion of the formation extending from 358 feet to 359 feet in area 18, as shown by indications in the drawing, essentially the same manner as that described in the preceding paragraph. Thus, the sealed portion of the well now extends from 358 to 360 feet. An analysis of a sample of the liquid produced from the remaining unsealed portion of the formation shows that the sample is essentially comprised of oil and the production rate is .51 gallon per minute.

From this information, the following data, tabulated below, in Table I is derived.

Table I

Vertical depth of producing area in ft.	Analysis of production fluid, ratio oil production to brine production in parts by weight	
	Oil	Brine
356 to 360	1	10
356 to 359	5	5
356 to 358	10	----------

Thus, the production profile of a well is obtained showing that the oil producing portion of the formation extends from about 356 to 358 feet and the water producing portion of the formation extends from about 358 to 360 feet. After a period of about 24 hours, the solidified solid material reverses or reverts to liquid form and is removed from the well, conventional formation plugging procedures are employed to plug the water producing portion of the formation, and thus the efficiency in recovering oil from the formation is considerably enhanced.

In view of the above description a number of variations of this procedure are obvious to those skilled in the art. For instance, instead of placing one layer of solid-forming material on top of another layer, the amounts of solid-forming material used can be successively increased or decreased after each previous portion reverts to liquid form and is taken from the well. Thus, an amount of solid-forming material could be set in the well and the production measurement taken. After the solid reverts to a liquid and is removed from the well a larger or smaller amount of solid-forming material could be used in successive measurements to obtain the production profile.

The reversible solid-forming material employable in the production well profiling method of the present invention generally will convert to a solid state or semi-solid state, i.e. it will not flow as a liquid under the well pressure, in the presence of water under conditions encountered in the well and in a reasonably short time, e.g. about 2 hours, and will normally remain in this state for generally a period of at least about 5 hours, preferably a period of at least about 24 hours up to about 36 hours before reverting or reversing into a liquid or a mobile state. Among the reversible solid-forming materials or compositions suitable for use in the method of the present invention are aqueous solutions of guar gum in concentrations of generally from about 1 to 2 or 5 weight percent. Silica gel can also be used through pH control, for instance, by adding acid to sodium silicate to solidify the material and making the solid basic to reverse it to liquid form. In addition the reversible solid-forming material may include other components, for instance, weighting agents. Moreover, as it is desirable to know the location of the solid-forming material in the well bore to insure its sealment of the proper portion of the formation, detecting agents can be added to the composition to give it a defined characteristic distinguishable from other fluids in the well. For instance, the composition can be given an electrical conductivity distinguishable from other fluids, e.g. brine, present in the well bore and thus can be located in the well with an electrical conductivity profiling unit.

The detection means employed for tracking the position of the solid-forming material in the well bore can vary. For instance, a soluble radioactive tracer may be injected into the material and a Geiger counter can be attached to a line to locate the solid-forming material and thus by checking the depth of the line, the position of the material is known. Although, as pointed out above, the solid-forming material can be given a defined electrical conductivity to enable detection in the well bore, conversely, as the brine in the well is essentially conductive, the solid-forming material can be made essentially non-conductive, such that the conductivity profiling unit will indicate the degree of current flow within the solid-forming material and brine. Accordingly, when the conductivity circuit is essentially good, the instrument is in the brine, and when the conductivity circuit is essentially poor, the instrument is in the solid-forming material. Thus, by raising and lowering the instrument the interface between the solid-forming material and the brine can be located and by checking the depth of the detecting instrument the location of the solid-forming material is known.

A device suitable for use in measuring the electrical conductivity of the fluids in the well bore is described in U.S. Patent 2,776,563. This device, known as a magnetic coupler, includes a magnetic core, and two electrically conducting coils essentially composed in two basic combinations. One of the combinations, conveniently referred to as a magnetic coupler sub, is essentially comprised of one of the coils, the first coil, surrounding the magnetic core, and fixedly mounted within a tubing structure. The other combination, conveniently referred to as the stinger, comprises a cable containing an insulated electrical conductor communicating with the other coil which is contained within a structure adapted to removably surround the first coil. Under operational conditions the magnetic coupler sub may be installed in a well string. Accordingly, when the position of a liquid of known electrical conductivity within the well bore is desired, the stinger is lowered into the well string and joined to the magnetic coupler sub, the well string is maneuvered until the liquid or the interface between liquids is located, and by noting the depth of the stinger, the position of the liquid or the interface between two liquids is known. Additionally, if a two-conductor cable is employed in the stinger arrangement, the stinger itself can be used as an integral detection unit.

It is claimed:

1. In a method for determining the production profile of a subterranean formation traversed by a well bore producing a plurality of fluids, the steps comprising analyzing the production fluid from the well to determine the amount of each of said plurality of fluids contained therein, injecting a sufficient amount of reversible solid-forming material into the well bore to seal a selected portion of the producing formation, analyzing the production fluid from the unsealed portion of the formation to determine the amount of each of said plurality of fluids contained therein; the difference between the amounts of each of said plurality of fluids from each determination being an indication of the production well profile.

2. The method of claim 1 wherein additional portions of the solid-forming material are injected into the remaining unsealed portion of the well to seal additional portions of the formation and the production fluid from the unsealed portion of the formation after such additions is analyzed to determine the amount of each fluid contained therein.

3. A method for procuring information as an aid in

determining the production profile of a subterranean formation traversed by a well bore including the steps of injecting a reversible solid forming material into a portion of the well bore to seal this portion of the formation and measuring the amount of fluid recovered from the unsealed portion of the formation as an aid in determining the production profile of the formation.

4. In a method for determining the production profile of a subterranean formation traversed by a well bore producing a plurality of liquids, the steps comprising injecting a sufficient amount of a reversible solid-forming material into the well bore to seal a lower selected portion of a producing formation, determining the amount of each of said plurality of liquids contained in the production fluid from the unsealed portion of the formation, injecting a sufficient amount of reversible solid-forming material into the well bore to seal a lower selected portion of the unsealed portion of the formation, and determining the amount of each of said plurality of liquids contained in the production fluid from the remaining unsealed portion of the formation; the difference between the amounts of each of said plurality of liquids being an indication of the production well profile.

5. In a method for determining the production profile of a subterranean formation traversed by a well bore producing fluid, the steps comprising analyzing the production fluid from the well to determine the amount of each type of fluid contained therein, injecting a sufficient amount of reversible solid-forming material into the well bore to seal a selected portion of the producing formation, analyzing the production fluid from the unsealed portion of the formation to determine the amount of each fluid contained therein; the difference between the amounts of each fluid from each determination being an indication of the production well profile.

6. The method of claim 5 wherein additional portions of the solid-forming material are injected into the remaining unsealed portion of the well to seal additional portions of the formation and the production fluid from the unsealed portion of the formation after each such addition is analyzed to determine the amount of each fluid contained therein.

7. In a method for determining the production profile of a subterranean formation traversed by a well bore producing liquid, the steps comprising injecting a sufficient amount of a reversible solid-forming material into the well bore to seal a selected lower portion of a producing formation, determining the amount of each type of liquid contained in the production fluid from the unsealed portion of the formation, injecting a sufficient amount of reversible solid-forming material into the well bore to seal a selected lower portion of the unsealed portion of the formation, and determining the amount of each liquid contained in the production fluid from the remaining unsealed portion of the formation; the difference between the amounts of each of the liquids being an indication of the production well profile.

8. In a method for determining the production profile

of a subterranean formation traversed by a well bore producing a plurality of fluids, the steps comprising analyzing the production fluid from the well bore to determine the amount of each of said plurality of fluids contained therein, injecting a sufficient amount of an aqueous solution of liquid reversible solid-forming material into the well bore to seal a selected portion of the producing formation, analyzing the production fluid from the unsealed portion of the formation to determine the amount of each of said plurality of fluids contained therein; the difference between the amounts of each of said plurality of fluids from each determination being an indication of the production well profile.

9. The method of claim 8 wherein additional portions of the aqueous solution are injected into the remaining unsealed portion of the well to seal additional portions of the formation and the production fluid from the unsealed portion of the formation after such additions is analyzed to determine the amount of each fluid contained therein.

10. In a method for determining the production profile of a subterranean formation traversed by a well bore producing a plurality of fluids, the steps comprising analyzing the production fluids from the well to determine the amount of each of said plurality of fluids contained therein, introducing a sufficient amount of liquid reversible solid-forming material into a string of tubing extending downwardly in the well bore to seal a selected portion of the producing formation, tracking and pressuring the material into the selected portion of the producing formation to solidify in and seal said portion of the formation, analyzing the production fluid from the unsealed portion of the formation to determine the amount of each of said plurality of fluids contained therein; the difference between the amounts of each of said plurality of fluids from each determination being an indication of the production well profile.

11. The method of claim 10 wherein the liquid reversible solid-forming material is an aqueous solution and additional portions of the aqueous solution are injected into the remaining unsealed portion of the well to seal additional portions of the formation, and the production fluid from the unsealed portion of the formation after such additions is analyzed to determine the amount of each fluid contained therein.

12. The method of claim 11 wherein the plurality of fluids include oil and water; the tracking is conducted with electrical conductivity detection means; and the aqueous solution includes electrical conductivity providing amounts of calcium chloride.

References Cited in the file of this patent

UNITED STATES PATENTS

1,406,682	Rathbone	Feb. 14, 1922
2,728,395	Howard	Dec. 27, 1955
2,781,663	Maly et al.	Feb. 19, 1957
2,814,947	Stegemeier	Dec. 3, 1957