June 3, 1958 T. O. ALLEN ET AL 2,837,164

WELL COMPLETION METHOD

Filed Oct. 12, 1955

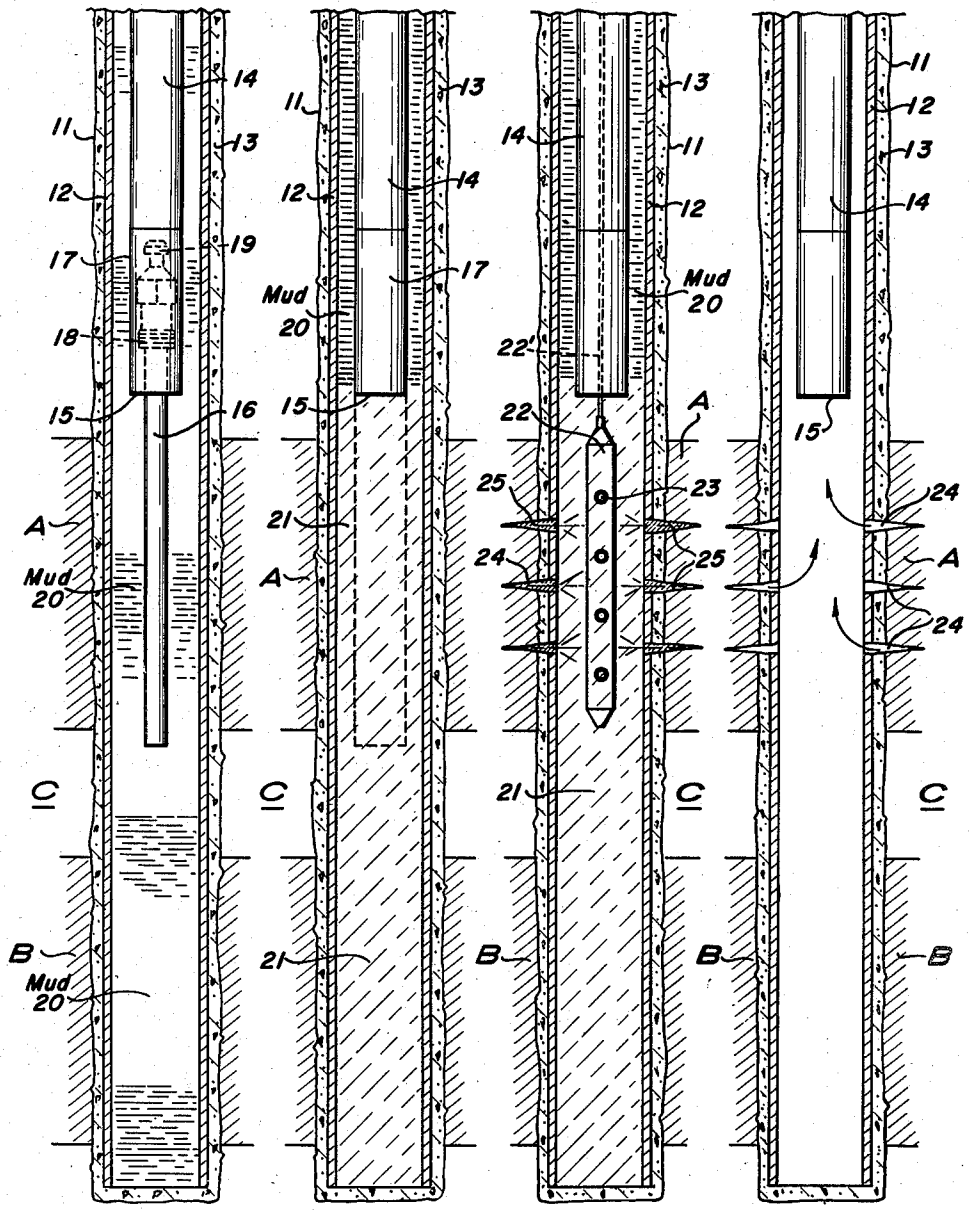


FIG. 1A FIG. 1B FIG. 1C FIG. 1D

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United States Patent Office 2,837,164 Patented June 3, 1958

2,837,164

WELL COMPLETION METHOD

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Application October 12, 1955, Serial No. 540,068

1 Claim. (Cl. 166—22)

The present invention is directed to a well completion method. More particularly, the present invention is concerned with forming clean perforations in a well bore. In this more specific aspects, the invention has to do with completing a well in which a well casing is perforated.

The present invention may be briefly described as a method for forming clean perforations and completing a well in a well bore penetrating a subsurface interval. The invention includes arranging in the well bore adjacent the subsurface interval a suspension comprising at least two finely divided solid materials in a liquid vehicle. The solid materials in the suspension are characterized by being chemically interacting and being separable from the liquid vehicle by filtration. The well bore is then perforated in the suspension by operating a perforator, such as firing a gun perforator inserted therein, whereby filter plugs are formed in resulting perforations which temporarily plug the perforations until chemical interaction between the solids in the filter plug causes destruction of the filter plug.

It is contemplated in the present invention that the well bore may have a casing arranged therein which will be perforated by the perforator, such as a gun perforator, which may be of a shape charge or bullet gun type. It is also within the purview of the present invention to complete a well in which a well bore or a well casing is perforated by firing a gun perforator in a first suspension comprising a finely divided solid material whereby a filter plug is formed in the perforations and thereafter contacting the filter plugs with a second suspension comprising a finely divided material, the finely divided materials in the two suspensions being capable of interacting and causing destruction of the plug. After the plug has been destroyed in either of the two modes described, the well may then be brought in and completed to produce earth fluids, such as oil and/or gas, water, and the like therefrom.

The present invention broadly contemplates replacing drilling mud in a well with a suspension of finely divided solids which forms a filter plug in the perforations and which is capable of reacting with another solid to destroy the filter plug. The suspension or fluid and the plugs formed therefrom may have the following characteristics:

(1) The fluid contains materials which would enter the perforations and temporarily plug the formations soon after perforating, thus reducing fluid loss to a relatively low level.

(2) This plug is self-destructible and either completely or partially reverts to a fluid or gas with time, temperature, and/or pressure at the bottom of the well.

(3) This self-destructible plug may result from the combination of a number of different types of chemicals intimately mixed together prior to placing them in the well bore, with destruction time being partially controlled by particle size.

(4) This self-destructible plug may be a single solid which is destroyed after a definite period of time due

to intimate contact with the carrying agent of fluid placed in the bottom of the hole at the time of perforating, or the plug may be partially destroyed by fluids in the formation following the perforating.

(5) This plug may not be completely destructible, but it is possible that only a portion of the plug will be destroyed, thus allowing the remainder of the plug to be cleaned out by fluid flow from the reservoir.

(6) Rather than being destroyed, the plug, after it is placed in the perforation, may shrink with time so that it becomes smaller than the perforation and can be easily flowed out of the perforation.

As an illustration of the type of suspension which may be used in which a filter plug is formed may be mentioned a suspension of calcium hydroxide and ammonium chloride in stoichiometrical proportions as shown in the following equation:

$$Ca(OH)_2+2NH4Cl=CaCl_2+2NH_3+2H_2O$$

With these two materials, the filter cake plug in perforations would break down into calcium chloride, ammonia, and water. By controlling the particle size, the self-destroying reaction could be a timed device to allow normal well completion operations to be completed prior to the destruction of the plug, since it is desirable that the plug remain essentially intact or be reformed rather rapidly to limit fluid loss into the formation. In addition, it is of great importance that the plug be self-destructible to the extent that it can be pushed from the perforation by fluids from the formation when the differential pressure is from the formation into the well bore. In order to get the desired weight characteristics for the perforating fluid which is located below the column of drilling fluid, it may be desirable to mix a certain percentage of barytes or other high density solids with the self-destructible materials which would form the perforation plug. In this invention, as previously stated, the high density weighting material would not be destroyed and tend to remain in the perforation while the self-destructible portion of the plug is being converted to a fluid or a gas. However, if at least 25 percent of the plug in the perforation is converted to a gas or liquid, the structure of the plug would be appreciably weakened by the destruction of a portion of the solid plug, thereby allowing the plug to be broken down and easily removed. In order to obtain desired weight, it may also be necessary to employ a fluid having a weight from 8 to 14 pounds without the addition of such materials as barytes.

A wide variety of finely divided solid substances may be used for forming the self-destructible filter plug. Among the types of substances which may be used in stoichiometrical proportions to react together to form non-plugging filter plugs are solid acids and bases, and solid oxidizing and reducing substances wherein the rate of self-destruction depends on the particular substances used and the amount of water added, if any is employed. As a general statement, it may be said that the solids may be capable of reacting together to destroy the filter plug within a time no greater than 24 hours. The time in which the filter plug will be destroyed by itself may vary depending on the temperature in the well bore which may range anywhere from about 80° up to about 300° F.

As pairs of solid inorganic acids and solid bases which may be used may be mentioned the following:

Boric acid and sodium hydroxide, silicic acid and sodium hydroxide, arsenic trioxide (with 0.5 equivalent of water) and sodium hydroxide, sulfamic acid and sodium hydroxide and sulfamic acid and sodium carbonate.

As typical examples of solid organic acids with solid bases which may be used may be mentioned the following:

Oxalic acid and sodium carbonate, oxalic acid and

calcium carbonate, adipic acid and sodium hydroxide, adipic acid and sodium bicarbonate, adipic acid and ammonium bicarbonate, adipic acid and sodium carbonate, fumaric acid and sodium carbonate, fumaric acid and sodium hydroxide, maleic anhydride and sodium hydroxide, maleic anyhdride and calcium carbonate, citric acid and sodium hydroxide, citric acid and sodium carbonate, tartaric acid and sodium hydroxide, benzoic acid and sodium hydroxide, benzoic acid and ammonium bicarbonate, benzoic acid and calcium carbonate, salicylic acid and sodium hydroxide, phthalic anhydride and sodium hydroxide, phthalic anhydride and calcium carbonate.

There are many solid mineral acid salts of weak bases which are reactable with inorganic bases to destroy a filter plug among which may be mentioned:

Ammonium sulfate and sodium hydroxide, ammonium mono H phosphate and sodiu hydroxide, ammonium thiocyanate and sodium hydroxide, ammonium thiocyanate and calcium hydroxide, ammonium oxalate and sodium hydroxide, ammonium citrate and sodium hydroxide, ammonium citrate and strontium hydroxide, ammonium chromate and sodium hydroxide, ammonium dichromate and sodium hydroxide, ammonium iodide and calcium hydroxide, ammonium bromide and calcium hydroxide, ammonium bifluoride and sodium hydroxide, ammonium carbonate and sodium hydroxide, ammonium bicarbonate and sodium hydroxide, ammonium alum and sodium hydroxide, ammonium alum and potassium hydroxide, ammonium acetate and sodium hydroxide, ammonium acetate and calcium hydroxide, ammonium nitrate and magnesium hydroxide, hydrazine sulfate and magnesium hydroxide, hydroxylamine sulfate and magnesium hydroxide, hydrazine hydrochloride and sodium hydroxide, guanidine hydrochloride and sodium hydroxide, ethanolamine hydrochloride and sodium hydroxide, ethylene diamine hydrochloride and sodium hydroxide, ethylene diamine hydrochloride and magnesium hydroxide, ethylene diamine hydrochloride and barium hydroxide, ethylene diamine hydrochloride and zinc oxide, butyl amine hydrochloride and sodium hydroxide, octyl amine hydrochloride and magnesium hydroxide, N, N dioctyl amine hydrochloride and sodium hydroxide, aniline hydrochloride and sodium hydroxide, aniline hydrochloride and magnesium hydroxide, aniline sulfate and magnesium hydroxide, aniline sulfate and zinc oxide, pyridine hydrochloride and sodium hydroxide, quinoline hydrochloride and sodium hydroxide, quinoline hydrochloride and magnesium hydroxide.

Of particular interest and usefulness in the present invention are solid ammonium salts reactable with solid bases; typical examples of which may be mentioned:

Ammonium chloride and magnesium hydroxide, ammonium chloride and sodium hydroxide, ammonium chloride and potassium hydroxide, ammonium chloride and lithium hydroxide, ammonium chloride and zinc oxide, ammonium chloride and tin oxide, ammonium chloride and aluminum hydroxide, ammonium chloride and aluminum oxide, ammonium chloride and beryllium oxide, ammonium chloride and antimony trioxide, ammonium chloride and nickelous hydroxide, ammonium chloride and calcium sulfide, ammonium chloride and barium sulfide, ammonium chloride and calcium lactate, ammonium chloride and ferrous lactate, ammonium chloride and magnesium lactate, ammonium chloride and manganese lactate, ammonium nitrate and calcium sulfide, ammonium nitrate and zinc oxide, ammonium nitrate and aluminum hydroxide, ammonium nitrate and aluminum oxide, ammonium nitrate and beryllium oxide, ammonium nitrate and antimony trioxide, ammonium nitrate and nickelous hydroxide, ammonium nitrate and ferrous lactate, ammonium nitrate and calcium hydroxide, ammonium nitrate and magnesium hydroxide, ammonium nitrate and magnesium lactate, and ammonium nitrate and manganese lactate.

It is possible to use solid reducing agents with solid oxidizing agents, as illustrated by the following reactants, to form self-destructible plugs on perforating a subsurface interval in a suspension thereof:

Hydroxylamine hydrochloride and ammonium nitrate, hydroxyl amine and sodium nitrate, hydroxyl amine hydrochloride and ammonium persulfate, hydrazine sulfate and ammonium nitrate, hydrazine sulfate and sodium nitrate, hydrazine sulfate and potassium nitrate, sulfamic acid and ammonium nitrate, paraform and ammonium nitrate, paraform and sodium nitrate, paraform and potassium nitrate, paraform and sodium nitrite, paraform and sodium chlorate, paraform and potassium chlorate, paraform and sodium bromate, paraform and potassium iodide, paraform and potassium perchlorate, paraform and ammonium chromate, paraform and ammonium persulfate, paraform and hydroxylamine hydrochloride, trioxane and ammonium nitrate, trioxane and sodium chlorate, hydroquinone and ammonium nitrate, hydroquinone and sodium nitrate, hydroquinone and sodium chlorate, hydroquinone and sodium bromate, hydroquinone and ammonium chromate, hydroquinone and ammonium dichromate, hydroquinone and chromium trioxide, hydroquinone and ammonium persulfate, hydroquinone and sodium borate, catechol and ammonium nitrate, catechol and sodium chlorate, o-phenylene diamine and ammonium nitrate, o-phenylene diamine and sodium chlorate, o-phenylene diamine and chromium trioxide, oxalic acid and ammonium nitrate, oxalic acid and sodium nitrate, oxalic acid and sodium chlorate, oxalic acid and hydroxylamine hydrochloride, paraform and ammonium nitrate, paraform and sodium nitrate, paraform and potassium nitrate, paraform and sodium nitrite, hydroxylamine hydrochloride and ammonium nitrate, hydroxylamine hydrochloride and sodium nitrate, hydrazine sulfate and ammonium nitrate, hydrazine sulfate and sodium nitrate, hydrazine sulfate and potassium nitrate, catechol and ammonium nitrate, oxalic acid and sodium nitrate, sugar and ammonium nitrate, sugar and sodium nitrate, paraform and sodium chlorate, paraform and potassium chlorate, paraform and sodium bromate, paraform and potassium iodide, paraform and potassium perchlorate, hydroquinone and sodium chlorate, hydroquinone and sodium bromate, catechol and sodium chlorate, sugar and sodium chlorate, paraform and ammonium chromate, hydroquinone and ammonium chromate, hydroquinone and ammonium dichromate, hydroquinone and chromium trioxide, o-phenylene diamine and chromium trioxide, cellulose and ammonium persulfate, paraform and ammonium persulfate, hydroxylamine hydrochloride and ammonium persulfate, cellulose and ammonium persulfate, cellulose and hydroxylamine hydrochloride, cellulose and picric acid, cellulose and zinc chloride, cellulose and aluminum chloride, wood flour and picric acid, wood flour and zinc chloride, wood flour and sodium peroxide.

It may be desirable to form the two solids in an emulsion or suspension by using a hydrocarbon vehicle as the suspending agent. As examples of the hydrocarbon vehicles which may be employed may be mentioned hydrocarbons boiling in the range from about 200° to about 750° F. and particularly petroleum naphthas and fractions in this boiling range. Kerosene and gas oil fractions may also be suitable. Under some conditions, it may be desirable to use lubricating oil fractions as the suspension material. In fact by virtue of the viscosity of the high boiling fractions, lubricating oil may be preferred under some instances. When other fractions are used, it may be desirable to add weighting agents to provide the necessary weight and/or viscosity to the fluids. Suitable thickening agents, such as metallic soaps of the fatty acids as exemplified by stearic, oleic, linoleic, linolenic, recinoleic, and the like acids, as well as fulfonic acids, may be used.

The proportions of the solids, for example, ammonium chloride and calcium hydroxide may range from about

4% to about 27% by weight of ammonium chloride with about 7% to about 22% by weight of calcium hydroxide.

In forming an emulsion, it may be desirable to form a water-in-oil emulsion which may contain up to about 5% to about 10% by volume of water. Suitable stabilizing materials or thickening agents and the like may be used if desired.

By varying the amount of water in the suspension, the time for self-destruction of the filter plug may be controlled.

It is desirable to control the particle sizes of the solids in the suspension and it is desirable that the solids may range from about a 2 mesh to about a 200 mesh with the particle sizes being proportioned in the intermediate ranges to provide the proper bridging characteristics to the particles in the suspension from which the filter plug is formed on perforating the casing.

In the present invention the perforation of the well bore or casing and formation, for example, when a gun perforator is employed, results in a filter plug being formed in the perforations due to the solid materials being carried into the perforations and the loss of water therefrom. This filter plug which, if not removed, would obviate the benefits of perforating the drill bore and/or casing since a solid plug would be formed which would obstruct passage of desirable fluid into the well bore. By providing a suspension which is self-destructible, the filter plug is destroyed at least partially which allows the well to be readily producible by flowing or swabbing as may be required.

The present invention also contemplates that the filter plug may be formed by firing a gun perforator in a suspension such as, for example, of calcium carbonate in an aqueous or hydrocarbon vehicle and thereafter contacting the resulting filter plugs with a suspension of another solid and an aqueous or oily vehicle such as ammonium chloride in water and/or an emulsion formed from hydrocarbon and water. In these instances, the second suspension or fluid would contact the filter plug for a period of time ranging from about 15 minutes to about 24 hours to cause destruction of the filter plug.

It will be seen from the foregoing description that the present invention is applicable to many variations.

The invention will be further described by reference to the drawing in which Figs. 1A to 1D represent a stepwise illustration of a preferred mode. Referring now to the drawing, in which identical numerals will be employed to designate identical parts, numeral 11 designates a well bore drilled from the earth's surface, not shown, to penetrate a plurality of subsurface earth formations, strata, intervals or zones A, B, and C. In this particular instance, intervals or zones A and C may be considered to be productive of hydrocarbons, such as oil and/or gas, and zone B is non-productive. Arranged in the well bore 11 is a casing 12 which is cemented in place with cement 13. Suspended from the well head of the well by means, not shown, is a tubing string 14 which may be permanently set in the well with its lower open end 15 above the intervals A, B, and C or which may be manipulatable in the well. When the tubing 14 is permanently set in the well, it may be desirable to employ a tubular extension member designated generally by the numeral 16 landed in the lower end of the tubing 14 and supported, anchored or suspended therein in a landing nipple 17 and sealed by a sealing means 18. The extension member 16 is provided with a fishing head or neck 19 for removal of the extension member 16 by means of a wire line not shown.

In the illustration of Fig. 1A the well is under control by means of drilling mud 20 arranged therein.

In Fig. 1B the drilling mud 20 in the well has been displaced at least in part with a suspension 21 of two finely divided solids as illustrated supra. The drilling mud may have been replaced or circulated out by lowering the tubing 14 as indicated by the dotted lines, if the tubing is not permanently set in the well, or by employing the tubular extension member 16 to reverse out at least part of the drilling mud or displace same with the suspension 21 which may have a weight and/or viscosity sufficient to displace the drilling mud at least in part.

In Fig. 1C a gun perforator, such as 22, provided with a plurality of bullets or shape charges 23, is lowered through the tubing 14 on a wire line 22' until it is positioned adjacent the interval A and then fired to perforate the casing 12, cement 13, and interval A to form perforations 24 which, immediately on firing of the gun perforator, become plugged with a self-destructible filter plug 25 which will destroy itself by interaction of the chamicals from the suspension after a period of time ranging from about 15 minutes up to about 24 hours. After this time has elapsed, the filter plug 25 will destroy itself at least in part and may be swabbed or flowed from the perforations 24 as shown in Fig. 1D and the well brought into production to produce the desirable earth fluids, such as oil and/or gas, water, and the like.

In accordance with the present invention, as stated hereinbefore, instead of firing the gun perforator 22 in a suspension comprising two finely divided solids, as shown in Fig. 1C, a suspension comprising only one of the finely divided solids may be used and the gun perforator fired in said suspension to form a filter plug, such as 25, and thereafter the first suspension may be replaced by a second suspension or fluid which may remain in contact with the filter plug for a time within the range from 15 minutes to 24 hours to cause destruction of the filter plug and allow the well to be brought into production, as shown in Fig. 1D.

The present invention is of considerable advantage and utility in that heretofore unless a well was perforated in a non-plugging fluid as set out in U. S. Patent 2,693,856, issued November 9, 1954, to Thomas O. Allen the perforations so formed would become plugged with drilling mud to render the operation sometimes entirely useless. In accordance with the present invention, the perforation is conducted in a suspension or fluid which will form a filter plug but which will destroy itself within a period of time within the range given.

The nature and objects of the present invention having been completely described and illustrated, what we wish to claim as new and useful and to secure by Letters Patent is:

A method for forming clean perforations in a well bore penetrating a subsurface earth interval having a casing arranged therein which comprises arranging in said well casing adjacent said interval a suspension comprising a mixture of at least two finely divided solid materials in a liquid vehicle, said solid materials being capable of chemically interacting and of being separable from the liquid vehicle by filtration, and then gun perforating said casing in said suspension whereby a filter plug is formed in the resulting perforations which temporarily plug said perforations until chemical interaction between the solids in the filter plug causes destruction thereof, said mixture being selected from the group consisting of mixtures of solid inorganic acids with solid inorganic bases; solid organic acids with solid inorganic bases; solid mineral acid salts of weak bases with inorganic bases; solid ammonium salts with solid inorganic bases; and solid reducing agents with solid oxidizing agents.

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