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[54] **CONSOLIDATING PERFORATION CHANNEL WALLS**

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[52] **U.S. Cl.**.....**166/292,** 166/281

[51] **Int. Cl.** **E21b 33/13**

[58] **Field of Search**.....166/281, 292, 293, 294, 295, 166/307

[56] **References Cited**

UNITED STATES PATENTS

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[57] **ABSTRACT**

In a well that opens into an unconsolidated reservoir formation through a perforated portion of grouted casing, the effective permeability is increased by flowing acid through the perforation tunnels to form channels between the grouting material and the reservoir formation and, while maintaining a fluid flow rate that keeps the channels free of solid particles inflowing a sand consolidating fluid that converts the walls of the channels to structures that are integral and permeable.

6 Claims, 2 Drawing Figures

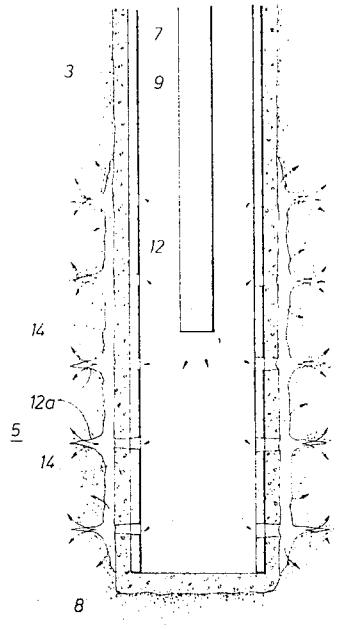


FIG. 1

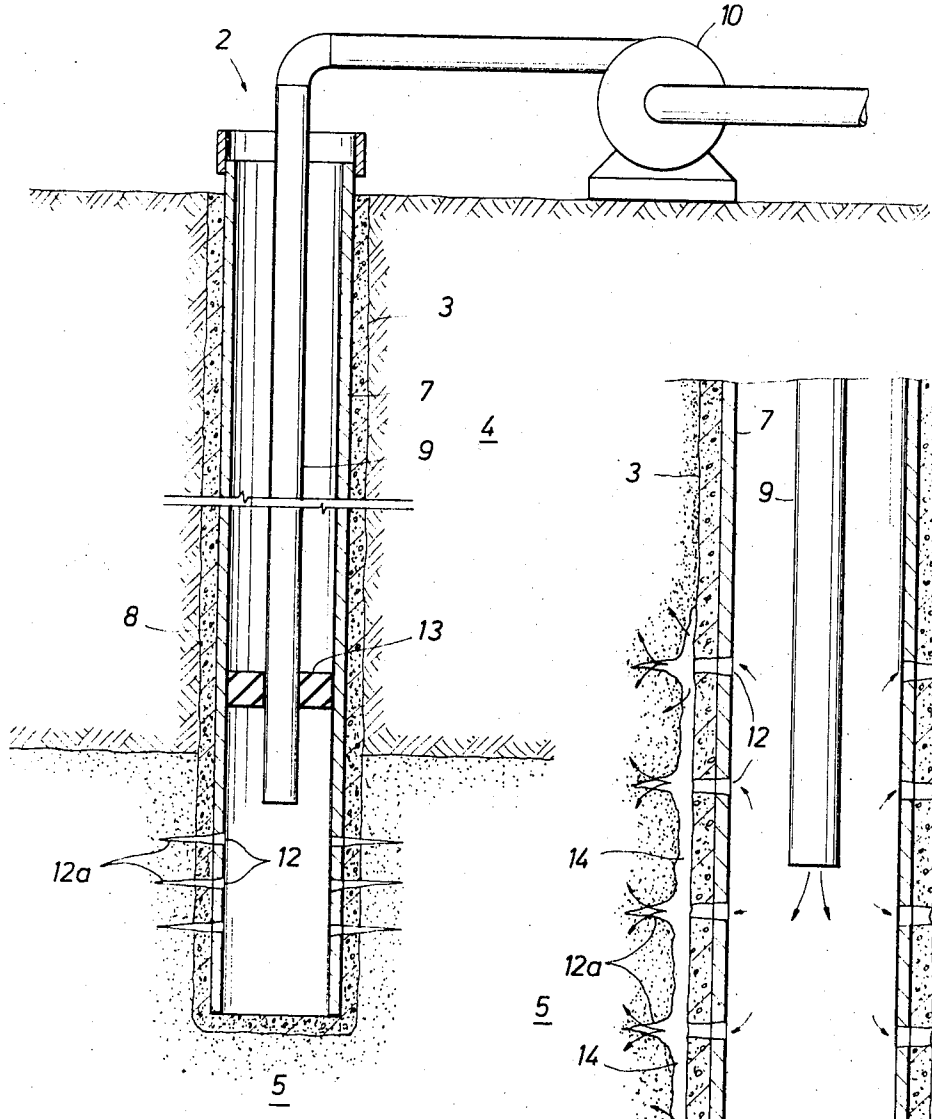


FIG. 2

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CONSOLIDATING PERFORATION CHANNEL WALLS

Related Patent Applications

This application relates to patent application Ser. No. 104,695, filed Jan. 7, 1971. The prior application relates to increasing the effective diameter of a borehole that contains a perforated portion of grouted casing within an unconsolidated reservoir formation. The borehole around the perforated casing is expanded by injecting fluid at a rate and pressure such that causes a hydraulic expansion of the borehole wall, and, while maintaining the expansion, a sand consolidating fluid is injected to convert the wall of the expanded borehole into a structure that is integral and permeable.

The present invention differs from the invention described in the prior application by injecting an acid through the perforations to form channels between the grouting material and the reservoir formation. The present process can be used in conjunction with the process of the prior application or can be used in other ways; for example, by injecting fluids at rates and pressures that are not sufficient to cause a hydraulic expansion of the borehole.

BACKGROUND OF THE INVENTION

The invention relates to a well-treating process for improving the injectivity or productivity of a cased and perforated well that is completed or opened into a reservoir or sand that is or is apt to become unconsolidated.

In wells that open into such reservoirs, the boreholes are usually lined with casings which are grouted, usually with cement, and perforated to form perforation tunnels extending from within the well to within the reservoir. Such wells are often treated by injecting an acid to clean out the perforation tunnels and/or to enlarge the interconnected pores or permeable matrix within a "tight" reservoir formation that has a low permeability. Wells completed into unconsolidated reservoirs are often treated by injecting sand consolidating fluids in order to bind the grains in the surrounding portions of the reservoir formations into integral permeable structures. The prior processes for performing such well treatments have often exhibited the disadvantage of providing only short duration improvements that tend to lose substantially all of the permeability increase that was provided.

SUMMARY OF THE INVENTION

A primary object of the present invention is the provision of a well treatment that causes a significant and durable increase in the injectivity or productivity of a cased and perforated portion of a well that opens into a reservoir that is or is apt to become an unconsolidated reservoir.

The invention is, at least in part, premised on a discovery that a significant and durable improvement in permeability can be obtained in response to a specific combination and sequence of steps. The well is acidized with an acid that is rapidly reactive with the reservoir and/or grouting material at the formation temperature. The acid is injected at a rate and pressure that causes it to flow along the interface between the grouting material (such as cement) and the surrounding earth formation. This dissolves and erodes solid material to form channels between the grouting material and the reservoir. A sand consolidating fluid is then injected through the channels, and into the surrounding reservoir at a rate sufficient to move sand grains from the interiors of the channels and press the grains against the walls of the channels. The step of injecting the sand consolidating fluid at a rate sufficient to move the granular solids, is important. The grains in and on the walls of the channels must be consolidated while the channel interiors are substantially free of solids — otherwise, permeability is apt to be lost, due to the crumbling of the channel walls.

DESCRIPTION OF THE DRAWING

FIG. 1 is a partially schematic cross-sectional view of a well and equipment for practicing this invention.

FIG. 2 is a similar illustration of a portion of such a well during one stage of operation.

DESCRIPTION OF THE INVENTION

In FIG. 1, well 2 contains borehole 3 that extends through an overburden comprising earth formations 4 and into an unconsolidated reservoir formation 5. The well contains casing 7 which is surrounded by grouting material 8, such as cement. Tubing string 9 extends from surface located pumping means 10 to a point in or near earth formation 5. The well borehole is opened into earth formation 5 through perforations 12 and perforation tunnels 12*a* that extend through the casing and cement. The portion of the borehole in which the casing is perforated is isolated from the remainder of the borehole by means of packer 13 surrounding tubing 9. The drilling and equipping of such a well can be accomplished by means of commercially available equipment and procedures.

FIG. 2 shows the perforated portion of casing 7 during a fluid injecting stage of the present invention. A fluid, such as an acid, is injected through tubing 9, perforations 12 and perforation tunnels 12a and into the surrounding earth formation, as shown by arrows. When such a fluid is an acidizing fluid that is relatively rapidly reactive and is injected in a manner that causes a flow along the interface between the cement and the surrounding earth formation, it tends to dissolve and/or erode solid materials and form channels 14. The channels 14 are located in or near the adjacent faces of the cement, or grout, 8 and the earth formation 5 and/or any mud cake which may have remained between those two materials. The channels 14 amount to extensions and/or interconnections of the perforations 12 and perforation tunnels 12*a*.

When fluid flows through channels, such as channels 14, and into walls comprising a permeable earth formation, such as formation 5, the stream of fluid tends to entrain granular solid particles, such as sand grains, perforation debris or the like, and displace the entrained material against the walls of the tunnels, through which the fluid is entering the surrounding earth formation. The extent of such a displacement increases with increases in the rate of flow. During such an injection, the rate of flow from the well to the surrounding reservoir can be significantly higher than was obtainable prior to the forming and cleaning of the channels and should be maintained at a rate sufficient

to prevent the sloughing or caving of the channel walls. The permeability of the opening between the well and the reservoir may thus become substantially equal to the natural permeability of the reservoir.

In accordance with the present invention, while the acid-leached channels between a casing and/or grouting material and a reservoir are being kept free of particles by the fluid being injected into the reservoir, the walls of the channels are consolidated into integral, permeable structures. In general, the channel walls can be consolidated by means of substantially any type of sand consolidating material or technique as long as the consolidation provides relatively strong and permeable structures and is adapted to be effected while fluid is flowing through the channels and into their walls at a rate sufficient to press granular solids against the walls of the channels. The fluids that are so injected can comprise an electroless metal plating solution, a resin-forming solution, a resin – overflushing fluid that follows a reactant-containing fluid and enhances and controls the formation of a resin or other solid material in order to consolidate a granular earth formation, or the like.

The injection of acid to form channels between the grouting material and/or exterior of the casing and the surrounding unconsolidated earth formation can be preceded or followed by steps such as temporarily terminating the injection of fluid into the earth formation and/or temporarily back-flowing fluid from the earth formation to the interior of a well. Such pulsating or incremental injections and/or backflows are advantageous in eroding and cleaning the channels by removing solids such as mud cake solids, sand grains, perforation debris, or the like, from the openings between the casing or grouting and the reservoir. The fluid which is injected during such pulsations to supplement the action of an acidizing fluid, can comprise one or more fluids such as a substantially inert aqueous liquid, e.g. a brine, an oil solvent, or an aqueous base, etc.

The acid which is injected to form the channels is preferably rapidly reactive with the grouting material and/or earth formation materials at the temperature of the reservoir. Such acids can comprise substantially any of the commercially available acidizing fluids, such as an aqueous mud acid (i.e., strong inorganic acid such as hydrochloric mixed with hydroflouric acid or a material which forms hydrofluoric acid), or strong inorganic acids such as hydrochloric, nitric, sulfuric, or a sequence of concentrated then dilute acidization solutions, or the like, containing no more of inhibiting materials such as reaction rate reducing and/or corrosion inhibiting materials than are needed in order to provide an adequate protection of the metal conduits and the like within the well. The mud acids are particularly preferred acidizing fluids where the reservoir formation is predominantly selicious and the hydrochloric acids are particularly preferred where the reservoir is predominantly carbonations.

In a preferred procedure, the acidizing fluid is formulated to provide a viscosity of less than about two centipoises at the formation temperature and is injected at a pressure at which the rate of fluid inflow into the earth formation is limited by the permeability of the opening between the borehole of the well and the surrounding earth formation. In such a procedure the injection pressure is preferably relatively high and is capable of displacing fluid into the reservoir at a rate significantly greater than the rate at which fluid is being displaced into (i.e. accepted by) the reservoir. When the acidizing fluid injection pressure is relatively high, a significant increase in the rate of fluid inflow can be detected when channels such as channels **14** are formed. The acidizing fluid can be injected in the form of a slug or a series of slugs separated by relatively inert spacer fluids such as water brine, or the like.

In general, the amount of an acidizing fluid (such as an aqueous **15** percent hydrochloric acid) that is injected to form channels in accordance with this invention is relatively small compared with that required for a conventional matrix acidization. For example, the volume of such an acid can range from about one-half to 5 barrels per foot of perforated interval where the borehole diameter is about 12 inches.

In a particularly preferred procedure, the injection of fluid to keep the interiors of the channels free of solids while consolidating the walls of the channels is conducted by injecting a relatively viscous electroless metal plating solution (e.g. having a viscosity of from about 5 to 15 centipoises at the reservoir temperature) at a pressure and rate sufficient to press solid particles against the walls of the channels. The injection pressure can advantageously be high enough to cause a radial outward displacement of the walls of the borehole and the walls of the surrounding channels, preferably without forming any fractures that extend away from the well. During such a procedure, the materials and techniques which are employed can comprise those of the type described in the prior patent application (identified above). The disclosures of that application are incorporated herein, by reference. In employing such a preferred procedure, an activator solution for activating electroless metal plating is injected during and/or after the formation of the channels. A relatively viscous electroless metal plating solution is then injected, at such a borehole expanding rate and pressure, in a volume sufficient to consolidate the walls of the channels to an extent that holds them in their expanded positions.

Alternatively, the channel-sweeping and channel wall-consolidating can be effective by injecting an inert or reactive overflushing fluid behind a slug of resin or other consolidating fluid. The rate at which the channel-sweeping fluid is injected through the channels during the consolidation of their walls is preferably adjusted to entrain or displace particles having a size and density equalling that of the median sized grains of the unconsolidated earth formation.

Particularly suitable epoxy resin sand consolidating formulations for use in the present process are disclosed in U.S. Pat. No. 3,339,663. In general, the sand consolidation step can utilize substantially any sand consolidating resin formulation and technique that is adapted to consolidate sand while fluid is being flowed through the sand. For example, the sand can be consolidated by a silicate intergranular bonding material that is formed by following a slug of a silicate-containing solution with a slug of a silicate precipitating reactant-containing solution or by following a slug of solution containing phenol-formaldehyde resin-forming

components with a slug of solution containing components for initiating such a reaction and/or overflushing the resin-treated earth formation, or the like.

What is claimed is:

1. In a process for treating a well that contains a grouted and perforated portion of casing in order to increase the effective permeability of the opening between the well and a permeable earth formation, the improvement which comprises:

flowing an acidizing fluid through the perforations and into the earth formation at a rate and pressure adapted to cause a fluid flow and errosion of channels proximate the interface between the grouting material and the earth formation; and

flowing fluid inclusive of a sand consolidating fluid through said channels and into the earth formation at a rate sufficient to urge solid particles against the walls of the channel, to keep the channels free of solids while consolidating the granular materials in or on the walls of the channels into an integral structure that is permeable.

2. The process of claim 1 in which:

said acidizing fluid has a viscosity of less than about two centipoises; and

said acidizing fluid is displaced into the earth formation in response to a pressure sufficient to cause a significant increase in flow rate in response to an increase in the permeability of the opening into the earth formation.

3. The process of claim 1 in which the rate at which said sand consolidating fluid is flowed through said channels is adjusted relative to the viscosity of that fluid to enhance the entrainment and displacement of grains having a size and density at least equivalent to those of median-sized grains of the earth formation.

4. The process of claim 1 in which said acidizing fluid comprises a mud acid formulation.

5. The process of claim 1 which comprises a hydrochloric acid formulation.

6. The process of claim 1 in which said sand consolidating fluid comprises an electroless metal plating formulation.

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