METHOD OF PLUGGING WELLBORE CASING PERFORATIONS

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ABSTRACT OF THE DISCLOSURE

A mass of solid pieces, e.g. pea gravel, of selected size for temporary plugging of perforations in a geologic formation, are injected down a wellbore penetrating the formation and emplaced in the perforations desired to be plugged by putting said pieces in a confined elongated substantially horizontal passageway adapted to receive a fluid at high pressure at an entrance end and to exit the fluid at the opposite end leading to the wellbore, and locating a fixed baffle in the path of said fluid prior to its contacting said particles, at an angle transverse to the flow of said fluid, said baffle closing the flow of fluid except for a relatively narrow distance near the bottom thereof, and thereafter injecting a fluid stream under high pressure, thereby imparting high turbulence to at least some of said particles and causing them to swirl along in said stream, out the exit of said passageway down the wellbore, and at least a portion thereof to be forced into plugging position in the perforations.

The invention is in the field of well treatments. By the term "well treatments" as used herein is meant the injection down a wellbore penetrating a fluid-bearing geologic formation; a selected fluid often containing slurried particulate solids for the purpose of treating the formation to attain such objectives as increased rate or duration of production of fluid therefrom, as by fracturing, acidizing, sand consolidation, emplacing filter media (known as filter packs) about the periphery of the wellbore, or extending, repairing, or in some way altering or improving the wellbore as by additional drilling, by emplacing, cementing, or perforating casing, or by cleaning out the wellbore and/or the passageways and channels in the formation.

In the treatment of a well, it is sometimes desirable to inject down the wellbore a mass of small stones to which reference is often made as pea gravel, pebbles, or merely gravel, by which it may sometimes be referred to hereinafter.

Pea gravel is an effective medium for temporarily plugging off perforations in a casing against fluid flow therethrough. The pea gravel varies in average piece size, but 4 to 6 mesh size (United States Bureau of Standards Sieve Series), e.g. an average of about 0.13 inch along its greatest dimension, is typical.

The injection and emplacement of pea gravel into casing perforations has long presented a problem because the pieces or individual pebbles are too large to be slurried and pumped by known slurry pumps. Heretofore, the technique employed has been to "lubricate" the pebbles down the wellbore which means to feed the pebbles into the casing and flush them along by means of a suitable liquid, e.g. water. This technique has obvious disadvantages from the standpoint of getting the pebbles when and where it is desired that they be placed. A need, accordingly, exists for an improved manner and means of emplacing pea gravel in a well. The invention meets this need by providing an apparatus and method whereby pea gravel may be conveniently, and with definitely more precision than has been generally achieved heretofore, emplaced in a wellbore, as in perforations in a casing, thereby temporarily to plug the perforations.

The apparatus used in the method of the invention comprises that of the type depicted in the annexed schematic drawing wherein: FIGURE 1 represents an elevational view partly in section, of such apparatus in the horizontal position in which it is employed and located at the site of a well to be treated, and FIGURE 2 represents an optional modification thereof.

In the drawing, the numerals thereon designate the following items or features: 1 is a chamber, e.g. pipe section; threadedly attached to the chamber by couplings 2 and 3 are swaged sections 4 and 5, section 4 comprising the front or inlet end of the apparatus (which is the further removed from the well during use) and section 5 comprising the outlet end during injection and hence closer or nearer to the well; threadeled nipples 6 and 7 are shown forming constricting ports on each of section ends 4 and 5, respectively; connecting means, e.g. appropriately threaded couplings 8 and 9, or other locking devices, are shown engaged with inlet line 10 and exit line 11, respectively; ports 12 and 13, provided with male threaded necks for introducing solid material, e.g. pea gravel, are shown at spaced intervals along the top of chamber 1; removable covers 14 and 15 are shown, provided with female threads for ports 12 and 13, respectively; baffle 16 is positioned inside the chamber near the entrance end thereof and secured in sealing engagement to the top and sides of the chamber (e.g., being welded thereto) but having a slot or opening 17 provided between the lower edge thereof and the bottom of the chamber.

Pea gravel 18 and carrier fluid 19 are shown in the apparatus as they would be in relation to each other at the beginning of a treatment.

The function of the baffle is to maintain the pea gravel in a separate compartment of the chamber from the entrance portion of the chamber, the latter being immediately adjacent to nipple 6 at the entrance end. The baffle thereby provides an impetus to a liquid being introduced into the chamber, at appreciable pressure through the entrance port, a swirling motion as it passes through the slot of the baffle, such swirling motion moving the gravel pieces along the chamber without objectionable bridging and in a tumbling manner so that they will readily flow out nipple 7 at the outlet end of the chamber.

It is understood that the drawing is illustrative of but one form of the apparatus of the invention. Variations therein, within the basic concept of the invention, will be apparent to those skilled in the art. For example, the chamber, although normally substantially circular in cross-section, as shown, may very well be elliptical or polygonal in cross-section. The inlet and outlet sections of the chamber need not be swaged nor the ports therein be centered as shown but may be located any place near the bottom or near the inlet and outlet ends, respectively. The threaded engagement means, as shown, may be replaced by bolted clamps or connections made fast by sweating (i.e. heating and fusing the mating materials). The size of the inlet for entrance of the carrier liquid is not highly critical. Similarly, the size of the outlet for the slurry comprising the pea gravel and carrier liquid is not critical, although the greatest dimension thereof should not be less than about three times the greatest dimension of the larger pea gravel pieces to eliminate any tendency to bridging at the outlet. The baffle may be at any effective angle, e.g. 90° or 45° to the longitudinal axis of the chamber, rather than at the angle shown. The baffle need not be perfectly flat but may be a convoluted S shape, if preferred. The slot in the baffle need not be that, as shown between the lower edge thereof and the bottom of the chamber, but may be slightly active, so long as it is located relatively near the bottom, and may, if desired, consist of a series of transverse horizontally related holes rather than a continuous slot.
Since the function of the baffle is to divert incoming carrier liquid so as to cause it to impinge on the pea gravel in a swirling motion and thereby dislodge it and move it rapidly along the chamber and thence out the outlet and down the wellbore, employing a minimum amount of carrier liquid, other small variations in the structure may be made within the spirit of the invention. For example, the relative size of the various parts of the structure are not highly critical so long as it is provided with: a baffle positioned near the inlet end and transverse to the longitudinal path through the elongated chamber and is provided with an opening therein near the liquid face of the chamber to permit a carrier liquid, introduced at a relatively high velocity, to impinge on solid pieces in the chamber; a port through which to introduce solid pieces of material into the chamber; an inlet for ingress of a carrier liquid; an outlet for egress of the solid pieces slurried in the carrier liquid; appropriate means to connect pipe 10 at the inlet of the chamber in series with a pumping unit; and a conduit in connection with pipe 11 at the outlet of the chamber to lead slurried pebbles to a disposal.

A convenient size apparatus of the invention is one having the following dimensions:

A chamber comprised of about a 3- to 5-foot-long pipe section having an inside diameter of from about 8 to 14 inches, at each end of which are firmly secured swages of 0.75-inch reduced pipe sections which reduce the diameter to about 1½ to 3 inches for attachment to inlet and outlet lines.

A modification of the apparatus of FIGURE 1 is shown in FIGURE 2 wherein pipe 20 is shown, provided with nozzle 21 through which a fluid, either gas or liquid, may be introduced at high pressure for the purpose of aiding in the forward movement of the pieces of gravel, particularly to aid in initiating such movement and eliminating bridging near the outlet of chamber 1. Although sometimes found helpful on occasion, general usage does not indicate a need, however, for the modification shown in FIGURE 2.

EXAMPLE 1

The practice of the invention will be more fully understood by a study of the following examples wherein three treatments were performed according to the invention.

A newly completely well located in Luling Branyon pool in Caldwell County, Texas, was to be treated. The treatment desired was to fracture each of three fluid-producing levels. The well was cased to a depth of 2,000 feet 15 degrees east of north, and the casing cemented in place. The treatment was conducted in three stages as follows:

Stage I. The casing was perforated by twelve perforations at the level of 1964 to 1973 feet. 300 gallons of about 15% by weight aqueous solution of HCl, containing a conventional inhibitor to corrosive attack of acid on metal, were pumped down the well until an initial fracture was indicated and acid attack on the formation had taken place.

Immediately thereafter, water, with which were slurried 5000 pounds of 20 to 40 mesh size sand, was injected down the well. The concentration of the sand was controlled to yield an initial concentration of 0.25 pound per gallon which was gradually increased to 1 pound per gallon of water. Additional fracturing was indicated by a sucession in the pressure registering at the wellhead. Then 5000 pounds of 10 to 20 mesh sand at a concentration of 1 pound per gallon, followed by 10,000 pounds of 8 to 16 mesh sand, were injected at a concentration of 1 pound per gallon of water.

Thereafter, 13 gallons of pea gravel (having an average size of about 0.25 inch along the greater dimension), which were of such size that they would enter and plug but not pass through the perforations, were placed in the chamber (behind the baffle) of the apparatus of the nature of that shown in FIGURE 1 of the drawing. A high velocity pumping unit was connected to the inlet end of the chamber.

About 1 barrel (42 gallons) of water was pumped into the inlet of the chamber, designated 4 in the drawing, at a rate of about 420 to 650 gallons per minute. The water so introduced passed below the baffle designated 16 in the drawing and flushed the pea gravel from the chamber, in a rapid continuous flow, out outlet nipple 7 of the apparatus into pipe 11, and into the wellbore (not shown). The gravel was displaced down the wellbore with additional water to the level of the perforations. Pumping was continued until a sufficient amount of the pea gravel was forced into the perforations to plug them, as was apparent by the abrupt rise at that time in the pressure registered at the wellhead.

Stage II. Continuing to maintain pressure on the well, to prevent displacement of the pea gravel from the perforations, being thus plugged at the already fractured zone, a perforating gun was lowered down the wellbore to an upper second level of between 1900 to 1904 feet and the casing perforated at that level.

Following the perforating, fracturing was repeated at the second (upper) level, employing substantially the same procedure and materials as in the perforations at Stage I, viz., the injection of an inhibited acid to create an initial fracture accompanied by some acidizing, a second injection of water having slurried therein 20 to 40 mesh sand (starting with a concentration of 0.25 pound per gallon increasing to 1 pound per gallon thereof), to expand the fracture or fractures created at the second level perforations, and thereafter injecting water containing 10 to 20 mesh sand followed by 8 to 16 mesh sand at a concentration of 1 pound per gallon of water.

Thereafter, 6 gallons of pea gravel (the average size along the greater dimension thereof being about 0.25 inch as in Stage I) were placed in the chamber of the apparatus of the type shown in FIGURE 1 of the drawing. A pumping unit, as in Stage I, was connected to the inlet end of the apparatus and the pea gravel fluid introduced and the pea gravel slurried therein flushed from the chamber into the wellbore, employing about 1 barrel of water as the flushing medium. The pea gravel was thus carried into and plugged the perforations at 1900 to 1904 level. The plugged condition was recognized as above, by the sudden rise in pressure at the wellhead. Pressure was maintained to retain the gravel in place.

Stage III. Following similar perforating and fracturing techniques to those of Stage II above, pressure was maintained on the wellbore while a perforating gun was lowered down the wellbore and perforations made in the casing at a third (and higher) level of between 1857 and 1891 feet. The formation was initially fractured as in the above stages by injecting 300 gallons of inhibited aqueous HCl solution down the well. Thereafter, water which was blended initially with 0.5 pound of 20 to 40 mesh sand, and thereafter with additional sand to increase the concentration to 1 pound per gallon, was injected down the well and into the formation until additional fracturing was indicated by the successive rise in pressure registered at the wellhead. Thereafter, while maintaining pressure on the injected fluid, water was injected with which was blended 8 to 16 mesh sand at a concentration of 0.5 pound and increasing it to 1 pound per gallon.

Fracturing was thus accomplished at all three levels. Pressure was released from the well and the well put back in production.

Production from the well thereafter was shown to have increased by about ten-fold as a result of fracturing, employing the apparatus and method of the invention.

Having described our invention, what we claim and desire to protect by Letters Patent is:

1. The method of plugging off perforations in the casing of a wellbore penetrating a geologic formation which comprises: putting a mass of solid pieces, the size of the individual pieces thereof being such that they will enter

2. The apparatus for putting a mass of solid pieces in the wellbore for plugging off perforations in the casing of a wellbore penetrating a geologic formation.
holes of the size of said perforations but will not pass therethrough, in a confined elongated passageway provided with an inlet at one end adapted to admit a fluid at high pressure therethrough and an outlet at the opposite end adapted to permit the exit of such fluid containing the solid pieces slurried therein to a conducting means leading to the interior of the casing at the level of said perforations; positioning a separatory means, at an angle of between about 45° and 90° to the longitudinal axis of said elongated passageway, between said mass of slurried pieces and the inlet end of said passageway, said separatory means making substantially sealing engagement against the passage of fluid into the inlet of said passageway, except for a narrow transverse opening near the floor of said passageway; introducing a fluid at high pressure into the inlet end of said passageway, forcing said fluid through the narrow transverse opening in said separatory means and causing the fluid to impinge on said solid pieces in a swirling motion; and continuing to force the solid pieces in a tumbling manner out the outlet end of said passageway, into said conducting means and thence down the casing whereby at least a portion of said solid pieces is brought to lodge in and thereby to close off said perforations so long as sufficient pressure is applied to said fluid.

2. The method according to claim 1 wherein a relatively small stream of additional fluid is caused to impinge at high velocity on that portion of said solid pieces which are located near the outlet of said passageway to initiate movement of the solid pieces near the outlet end and insure substantially the prevention of bridging thereof across said outlet.

3. The method according to claim 1 wherein said separatory means is positioned so that a slot of less vertical height than the larger dimension of said solid pieces is provided between the lower edge of said separatory means and the floor of said passageway.

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