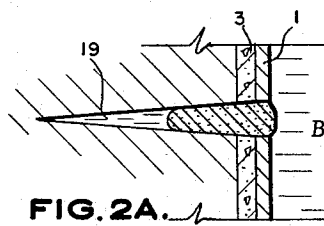
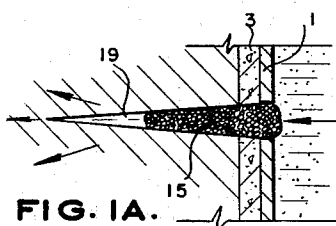
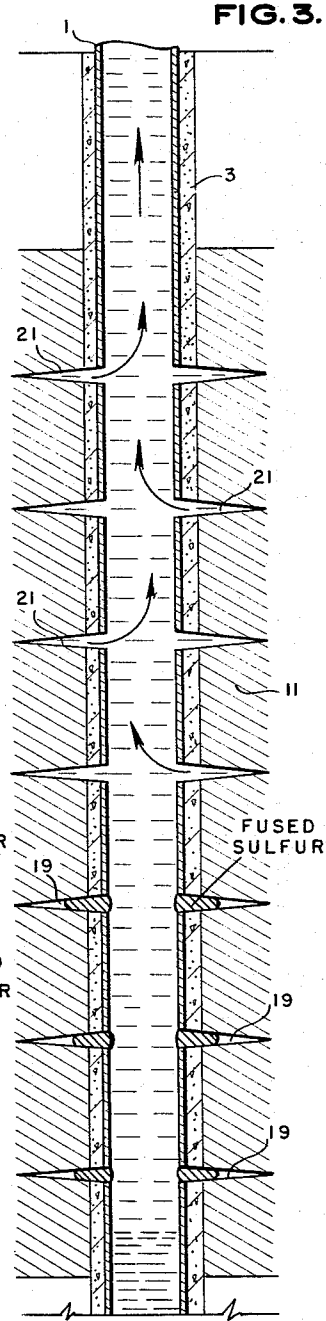
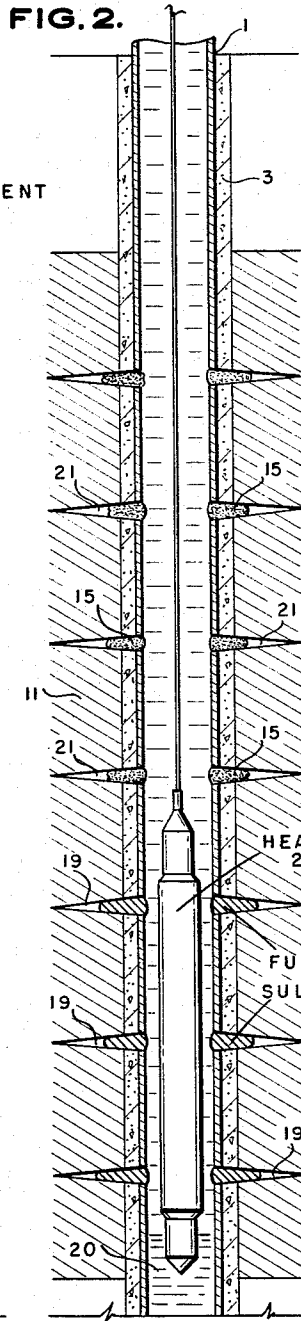
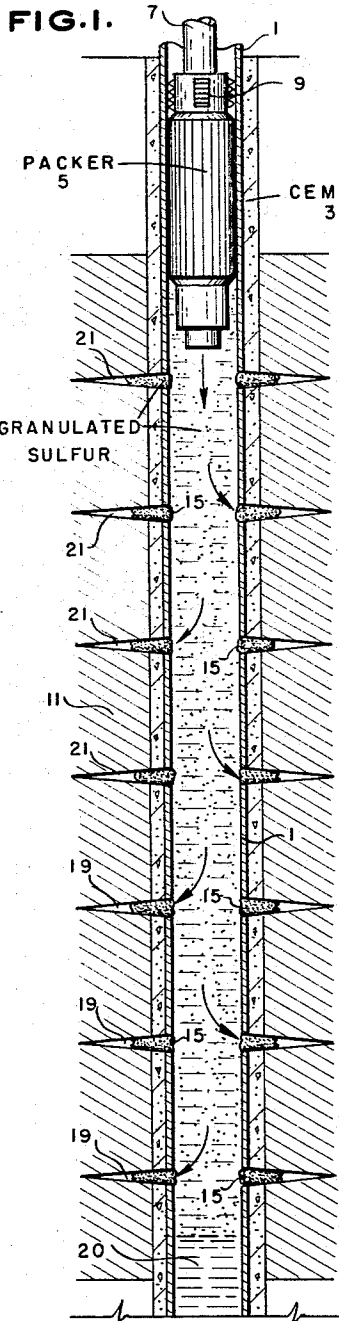


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RECOMPLETION OF WELLS

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3,275,077

RECOMPLETION OF WELLS

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This invention relates to recompletion of wells, and more particularly to a technique for plugging only selected perforations in a cased perforated well bore.

During recompletion of wells it is the usual practice to "kill" the well before recompletion operations are begun in order to stop the flow of connate earth fluids into the well bore. After the recompletion operations have been finished, often it is desirable to plug certain of the perforations in the well bore, such as when it has been found that water is entering the well through one or more of the lowermost perforations. It has been the usual practice to squeeze a cement slurry into all of the perforations and, after the cement has hardened, to re-perforate the well bore. Such an operation is undesirable for at least two reasons. The technique of cementing and perforating is expensive inasmuch as a considerable amount of pipe handling and wire line operations are necessary. Furthermore, perforation inevitably causes a certain amount of damage to the casing and cement sheath therearound. In addition, the cements currently in use may prematurely set in the casing and/or tubing string and lead to expensive fishing operations, and may even cause loss of the well.

In accordance with the teachings of the present invention, particulated sulfur is packed into all of the perforations, and the sulfur in selected perforations is heated until the particulated sulfur therein is fused together. Thereafter, the well is produced to remove the unfused sulfur particles from the perforations other than the selected perforations.

Objects and features of the invention which are not apparent from the above discussion will become evident upon consideration of the following detailed description of the invention taken in connection with the accompanying drawing, wherein:

FIGS. 1, 2, and 3 are schematic presentations of an oil well installation, partially in cross section, illustrating several of the steps performed in accordance with the invention; and

FIGS. 1A and 2A are enlarged views of portions of FIGS. 1 and 2, respectively, for the purpose of better illustrating the manner in which sulfur is packed into perforations and fused therein.

Preparatory to well operations in accordance with the invention, there is formed at the earth's surface a suspension of particulated sulfur in a liquid vehicle which preferably is a solids-free oil-in-water or water-in-oil emulsion liquid. The liquid vehicle should be relatively free of plugging type solids such as sand, clay, and barites. A number of suitable liquid vehicles are commercially available, such as Invermul, sold by the Baroid Division of the National Lead Company; Protectomul, sold by the Magnet Cove Barium Corporation; and "Black Magic," sold by Oil Base, Inc. However, the preferred vehicle is oil-in-water emulsion comprising about 83% to about 98% by volume of water, from about 1.5% to about 10% by volume of oil, a water-soluble salt of lignin sulfonic acid in the range from about 0.75% to about 1% by weight to which is added from about 1 to 100, and preferably from about 5 to 50 pounds of particulated

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sulfur per barrel of water and oil, said sulfur having particle sizes in the range of 4 to 325 mesh. The oil may suitably be a petroleum fraction boiling in the kerosene, diesel, and gas-oil boiling range, and suitably may boil in the range from about 350° to about 850° F. Preferably, the gravity of the oil is in the range from about 42° to about 45° API. The water-soluble salt of lignin sulfonic acid suitably may be sodium, calcium, magnesium, or potassium salt, or mixing thereof. The salt functions as an emulsifying agent. In making the emulsion, either fresh or salt water may be used. It is preferable to use salt water, such as calcium chloride brine, calcium chloride and sodium chloride brine, and calcium chloride and calcium nitrate brines. Other brines, such as zinc chloride, sodium nitrate, and the like may be employed. It is desirable to use brines or salt solutions in the water phase in that the density of the water emulsion may be controlled in the range from about 8.5 to about 14 pounds per gallon.

With reference now to the drawing, in FIGS. 1, 2, and 3 there is shown a well installation comprising a casing 1 which is bonded to surrounding earth formations by a sheath 3. The casing is illustrated as having been perforated at the level of a productive earth formation 11 to form a plurality of perforations 19 and a plurality of perforations 21. It is desired to plug the perforations 19 and to thereafter produce the well through the perforations 21. To this end a tubing string 7 is run into the well having at its lower end slips 9 and an expandable packer 5. The packer seals the space between the lower end of the tubing 7 and the casing 1. The slurry described above containing the granulated sulfur particles is pumped down the tubing string 7 and sufficient hydraulic pressure is exerted to force the fluid carrier and the granulated sulfur particles into the perforations 19 and 21. Some of the fluids 20 previously in the well bore will be forced out, leaving the level of the fluids 20 at or below the lowermost of the perforations 19. The granulated sulfur will pack into all of the perforations 19 and 21 as best illustrated in FIG. 1A, but after the nodules 15 have formed, there will be no tendency for a pack to form in the bore of the casing 1. The packer 5 may be deflated or decompressed to permit circulation of fluids up the annulus between the casing 1 and the tubing 7, and the slurry remaining in the bore of the casing 1 may be circulated to the earth's surface and removed from the well.

Thereafter, a borehole heater 23 is lowered into the well adjacent the perforations 19 to be sealed. Typically, the borehole heater may be either electrically activated or gas fired and may be of a number of types well known to the art. The heater is activated to heat the sulfur particles in perforations 19. As is well known, sulfur does not have a sharp melting point, some of the particles melting before others of the particles. When the sulfur has been heated to melt a significant portion of the particles thereof, heating is discontinued. Inasmuch as many of the sulfur particles have become liquefied, the particles will fuse together to form solid plugs in the perforations 19, as best shown in FIG. 2A. Since the sulfur nodules in perforations 21 have not been particularly affected by the heater 23, the sulfur particles therein remain discrete. Thereafter, as illustrated in FIG. 3, the well is placed on production either by pumping or by naturally flowing the well so that the sulfur particles in perforations 21 are washed out of the perforations into the well bore and removed from the well. The fused plugs will adhere to the walls of the perforations in which they are formed, and so will remain in place therein as illustrated in FIG. 3.

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An alternate method, desirable under some circumstances, involves placement of the sulfur slurry in the perforations as follows:

(1) Run tubing string 7, without a packer 5, into the cased borehole until the lower end of the tubing string is below the lowest perforation.

(2) Circulate the sulfur slurry down the tubing string and back up the tubing-casing annulus until the slurry contacts and is opposite all perforations.

(3) Now, with sulfur slurry in contact with and opposite all perforations, stop fluid circulation and increase fluid pressure in the borehole so as to cause filtration of the slurry into the perforations and build-up of the sulfur node 15.

(4) After sulfur nodes are formed, circulate out excess sulfur slurry remaining in the well bore.

(5) Proceed, using the wire line heater, to consolidate the sulfur selected perforations as described above.

Still another method which may be desirable under certain well conditions and which eliminates use of tubing string 7, is to pump the sulfur slurry directly down the casing string, forcing well fluids 20 ahead of the slurry and back through perforations into the formation. When sulfur slurry reaches the perforation, the pumping pressure will increase as sulfur nodes form in the perforations, restricting fluid flow. This increased pressure is held a sufficient time to insure adequate node build-up, then a wire line heater runs to consolidate selected perforations as before. Production of formation fluids through perforations 21 removes excess slurry from the well bore.

It is apparent from the above description of the above invention that many of the steps required according to prior art techniques for cementing and reperforating a well have been eliminated. The number of wire line and pipe operations in the well have been reduced to a minimum. The invention results in selective plugging of perforations in a well that will be found to be extremely effective and reliable.

Having described the principle of the invention and the best modes in which we have contemplated applying that principle, we wish it to be understood that the apparatus described is illustrative only and that other means can be employed without departing from the true scope of the invention.

What is claimed is:

1. The method of plugging selected perforations in a cased and perforated well bore, comprising:

packing particulated sulfur into all of the perforations; heating the particulated sulfur in said selected perforations until the particulated sulfur therein is fused together to form a plug that adheres to the walls of the perforations; and

producing the well to remove the unfused sulfur particles from the perforations other than said selected perforations.

2. The method of plugging selected perforations in a cased and perforated well bore, comprising:

packing particulated sulfur into all of the perforations; activating a borehole heater adjacent said selected perforations to be plugged to heat the particulated sulfur therein until the heated sulfur particles fuse together to form a plug that adheres to the walls of the perforations; and

producing the well to remove the unfused sulfur particles from the perforations other than said selected perforations.

3. The method of plugging selected perforations in a cased and perforated well bore, comprising:

heating the particulated sulfur in said selected perforations until the particulated sulfur therein is fused together by lowering a borehole heater adjacent said selected perforations to be plugged, and activating the borehole heater to heat the particulated sulfur in perforations thereadjacent until the heated sulfur

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particles are fused together to form a plug that adheres to the walls of the perforations; and producing the well to remove the unfused sulfur particles from the perforations other than said selected perforations.

4. The method of plugging selected perforations in a cased and perforated well bore, comprising:

forming a suspension of particulated sulfur in a solids-free oil-in-water emulsion liquid vehicle;

squeezing said liquid vehicle and particulated sulfur suspension into all of the perforations until the perforations are packed with particulated sulfur;

heating the particulated sulfur in said selected perforations until the particulated sulfur therein is fused together to form a plug that adheres to the walls of the perforations; and

producing the well to remove the unfused sulfur particles from the perforations other than said selected perforations.

5. The method of plugging selected perforations in a cased and perforated well bore, comprising:

forming a suspension of particulated sulfur in a solids-free oil-in-water emulsion liquid vehicle;

squeezing said liquid vehicle and particulated sulfur suspension into all of the perforations until the perforations are packed with particulated sulfur;

lowering a borehole heater adjacent said selected perforations to be plugged;

activating the borehole heater to heat the particulated sulfur in the perforations thereadjacent until the heated sulfur particles are fused together to form a plug that adheres to the walls of the perforations; and

producing the well to remove the unfused sulfur particles from the perforations other than said selected perforations.

6. The method of plugging selected perforations in a cased and perforated well bore, comprising:

forming an emulsion comprising about 83% to about 98% by volume of water, about 1.5% to about 10% by volume of oil, a water-soluble salt or lignin sulfonic acid, and from 1 to 100 pounds of particulated sulfur per barrel of water and oil, said sulfur having particle sizes in the range of from 4 to 325 mesh, said water-soluble salt of lignin sulfonic acid and oil being present in a ratio of about 0.1 to about 0.25:1 volume percent, said emulsion having a density within the range of from about 8.5 to about 14 pounds per gallon;

squeezing said emulsion into all of said perforations until the perforations are packed with particulated sulfur;

heating the particulated sulfur in said selected perforations until the particulated sulfur therein is fused together to form a plug that adheres to the walls of the perforations; and

producing the well to remove the unfused sulfur particles from the perforations other than said selected perforations.

7. The method of plugging selected perforations in a cased and perforated well bore, comprising:

forming an emulsion comprising about 83% to about 98% by volume of water, about 1.5% to about 10% by volume of oil, a water-soluble salt of lignin sulfonic acid, and from 1 to 100 pounds of particulated sulfur per barrel of water and oil, said sulfur having particle sizes in the range of from 4 to 325 mesh, said water-soluble salt of lignin sulfonic acid and oil being present in a ratio of about 0.1 to about 0.25:1 volume percent, said emulsion having a density within the range of from about 8.5 to about 14 pounds per gallon;

squeezing said emulsion into all of said perforations until the perforations are packed with particulated sulfur;

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lowering a borehole heater adjacent said selected perforations to be plugged;
 activating the borehole heater to heat the particulated sulfur thereadjacent until the heated sulfur particles are fused together to form a plug that adheres to the walls of the perforations; and
 producing the well to remove the unfused sulfur particles from the perforations other than said selected perforations.

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