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Karnes

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[54] **SELECTIVELY PERFORATING AND TREATING A CASED WELL**

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[52] **U.S. Cl.** **166/297**

[51] **Int. Cl.** **E21b 29/00**

[58] **Field of Search** 166/297, 298, 50, 285; 175/4.51

[56] **References Cited**

UNITED STATES PATENTS

2,935,131	5/1960	McCune	166/297
2,952,319	9/1960	Popham	166/297 X

OTHER PUBLICATIONS

Webster et al., Gulf Oil Corp., Journal of Petroleum Technology, June, 1965.

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[57] **ABSTRACT**

A process for forming and individually treating perforations at different depths within a cased well is improved by forming a slidable mechanical seal between a tubing string and the casing, lowering the tubing string to near the top depth to be perforated, sealing between the tubing and the casing, forming and treating at least one perforation, and then repeating the sequence at different depths, while maintaining the slidable seal.

5 Claims, 3 Drawing Figures

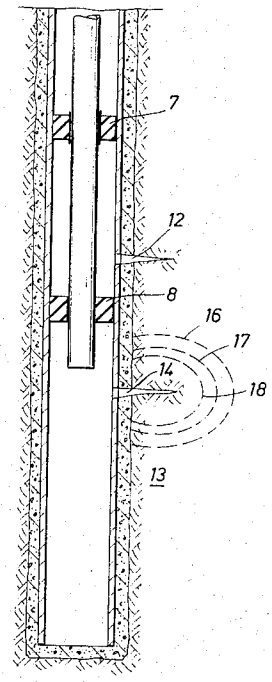


FIG. 3

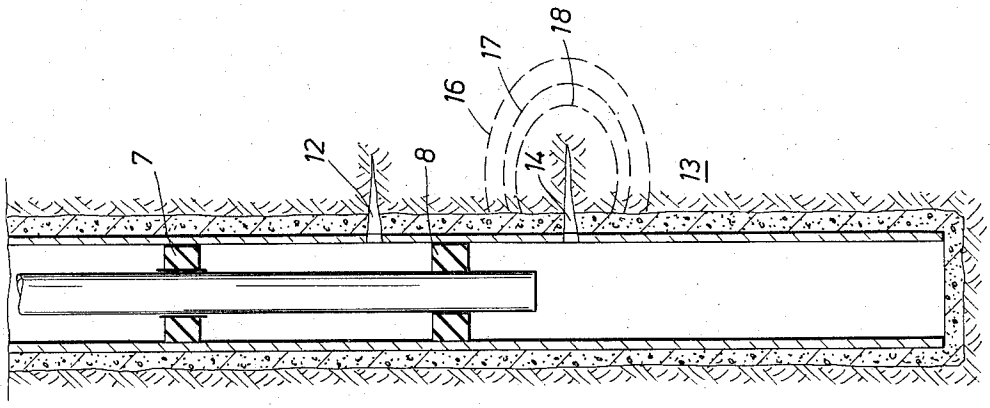


FIG. 2

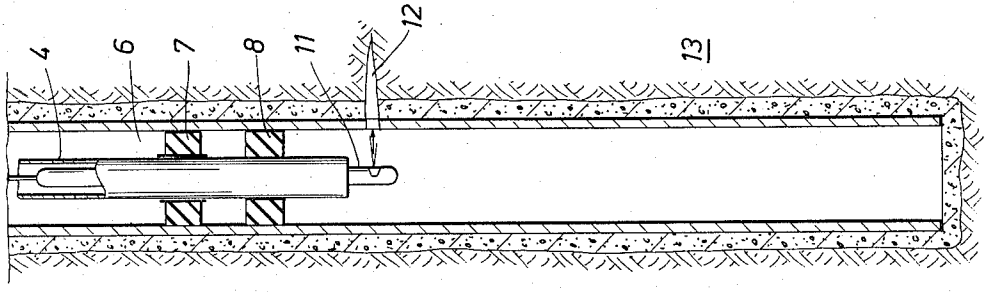
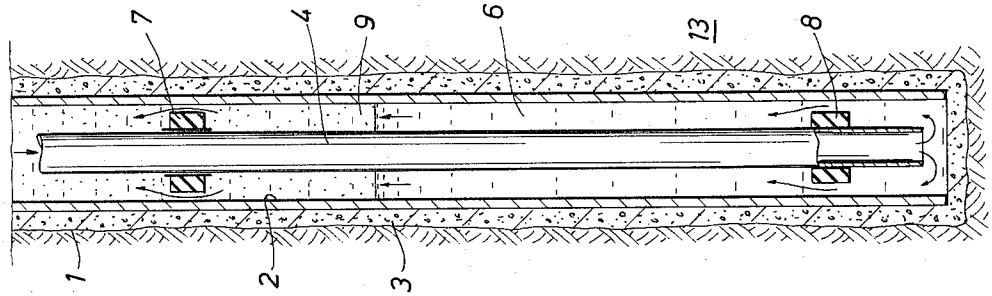


FIG. 1



SELECTIVELY PERFORATING AND TREATING A CASED WELL

BACKGROUND OF THE INVENTION

This invention relates to completing a cased well by perforating the casing and cement or other grouting material to provide an opening or perforation tunnel into the surrounding earth formation. More particularly, the invention relates to individually forming and treating one or more perforations at or near a selected depth and then repeating such an operation at at least one other depth.

It has heretofore been relatively difficult and expensive to form and individually treat perforations at different depths within a cased well. The prior procedures have involved steps such as running in a tool for isolating a small area or depth section within the casing (e.g., by means of a hollow pad or straddle packer arrangement), perforating and treating the isolated portion or section of casing and then returning the equipment to the surface to reload it for use at a different depth. Such procedures are as described in U.S. Pat. No. 3,153,449 and 3,174,547. Where such perforations are opened into a reservoir containing unconsolidated sands, it has been found to be desirable to use an additional precaution of protecting the first opened perforations by filling them with a temporary plug of gelled material; e.g., as described in U.S. Pat. No. 3,593,797.

SUMMARY OF THE INVENTION

The invention relates to a process for forming and individually treating perforations at different depths within a cased well. A conduit is positioned within the well casing and utilized to displace a fluid of selected composition into at least a portion of the space between the conduit and the casing along the depth interval to be perforated. Above the depth interval to be perforated, the passageway between the conduit and the casing is sealed with a slidable mechanical seal that is adapted to remain sealed while the conduit is moved. While maintaining the slidable seal, the conduit is moved to the extent required to position its lower end above the top depth to be perforated. The passageway between the lower end portion of the conduit and the casing is mechanically sealed. A perforating device and a means for circulating fluid are operated to form and fluid-treat at least one perforation near the top depth to be perforated. The moving of the conduit, the sealing of the passageway between the lower end portion of the conduit and casing, and the operating of a perforating device and a means for circulating fluid is then repeated, at least one additional time, to form and treat at least one additional perforation at a different depth within the well.

DESCRIPTION OF THE DRAWINGS

FIGS. **1**, **2** and **3** are schematic illustrations of three stages of completing a well in accordance with this invention.

DESCRIPTION OF THE INVENTION

FIG. **1** shows an initial stage of employing the invention in a well in which borehole **1** contains a casing string **2** which is surrounded by a sheath of cement **3**. A conduit **4**, such as a tubing string, is positioned within

the borehole and utilized to circulate a fluid of selected composition, fluid **6**, into the space between the conduit and the casing. The conduit **4** is equipped with a pair of remotely actuatable sealing means **7** and **8**, for forming mechanical seals that are each adapted to prevent the vertical flow of fluid past the point of sealing. The uppermost sealing means **7** is arranged to form a slidable mechanical seal that is adapted to remain sealed while the conduit **4** is moved relative to the sealing means. The fluid is preferably inflowed through the conduit **4**, as indicated by arrows. The inflowing is preferably continued until fluid **6** has displaced the fluid which was initially present in the borehole, fluid **9**, upward so that a column of fluid **6** extends through out the depth interval to be perforated and extends above the depth at which a slidable seal is to be formed.

The sealing devices and techniques used in this invention can be those which are commercially available. For example, the sealing means **7**, for forming a slidable seal, can be substantially any remotely actuatable packer that is so arranged; such as a Brown Oil Tool EMJAY Packer that is arranged to maintain a seal around a relatively lone section of a flush-joint tubing string, such as a Hydril CS tubing string. The sealing means **8** can be substantially any remotely actuatable packer such as a Brown Oil Tool Husky M–1 mechanically set packer.

The composition of the fluid **6**, which is spotted along the interval to be perforated, is preferably adjusted to suit factors such as the particular treatment to be applied to the perforations and adjacent portions of subterranean earth formations, the temperature and pressure and composition of the fluids in such earth formation, and the like. Suitable fluids include: clear aqueous solutions of inert and/or acidic or alkaline materials, such as aqueous brines or acids or bases; aqueous well workover solutions, such as thickened aqueous slurries containing chalk particles, polyoxyethylenic alcohol water thickeners, or the like; oil-based slurries such as a chalk-particle-stabilized emulsion of water-in-oil; oil solvents, such as hydrocarbons; or the like.

As shown in FIG. **2**, while the selected fluid **6** is in place, a slidable seal is formed above the depth interval to be perforated, e.g., by actuating a sealing means **7** to seat a packer. While maintaining the slidable seal, conduit **4** is moved to position its lower end above the top depth to be perforated, and the sealing means **8** is actuated to seal the space between the lower end portion of the conduit and the casing. This step forms a second seal near, but above, the top depth to be perforated. It is effected, for example, by actuating a sealing means **8** to seat a packer. A perforating device, such as wire line controlled perforating gun **11**, is operated to open at least one perforation, such as perforation **12**, at or near the top depth to be perforated.

Such perforations can be formed by means of jet, or bullet, types of perforating guns, fluid abrasion types of perforating devices, or the like, that are adapted to form perforations that provide tunnels, or passageways, that extend into the surrounding earth formations **13**. The perforating devices can be arranged so that fluids can be circulated through conduit **4** to flow into or out of the perforation **12** with or without the removal of the perforating device from the conduit.

At the stage shown in FIG. **2**, any fluid injected or produced through the conduit **4** must flow selectively through the perforation perfation **12** and into or out of

the adjoining portion of earth formation **13.** A fluid-circulating means (not shown) is operated to fluid-treat perforation **12** and/or the adjacent earth formation.

As known to those skilled in the art, numerous types of fluid-circulating devices and treatments can be employed for fluid-treating a well casing perforation. For example: the conduit **4** can be arranged to include low pressure chambers that are adapted to cause a back-surge circulation of fluid through the perforation into the casing as soon as the perforation is formed. This washes debris out of the perforation tunnel and into the casing. Surface located pumping means can be utilized to inject solvents, such as oil solvents, acids, bases, or the like into the perforation and/or the surrounding earth formation; etc.

Where the specific gravity of the fluid **6** that is spotted in the zone to be perforated is substantially equal to that of the fluid that is injected or produced through perforation **12,** the fluid **6** in the casing below the sealing means **8** tends to remain relatively static and undergo only a minimum of mixing with, or displacement by, the injected or produced fluid. Where the density of the fluid **6** is greater than that of the injected or produced fluid, the latter tends to displace the fluid **6** from the portion of the casing between the perforation **12** and the sealing means **8.** Alternatively, where the fluid **6** is lighter than the injected or produced fluid, the latter tends to displace the fluid **6** from all or most of the portion of the casing between the perforation **12** and the bottom of the well (or the location of a bridge-plug or other casing plugging means that has been arranged to isolate the lower portion of a well that extends below the depth interval to be perforated).

As indicated in FIG. **3,** after the perforation **12** has been formed and treated, the conduit **4** is moved (while maintaining the slidable seal formed by the means **7**) to position its lower end above the then top depth to be perforated, e.g., the depth location of perforation **14.** During such movements of the conduit **4,** the pressure on the fluid **6** is preferably kept substantially equal to the earth formation fluid pressure at the depth of the interval in which the perforations are formed. This prevents any significant inflow or outflow through an open perforation, such as perforation **12,** during the movement of the conduit. Thus, if a treatment fluid has been injected through such an open perforation and spotted within the adjacent portion of the earth formation **13,** that fluid tends to remain static in the position it was spotted. The sealing means **8** is, of course, operated so that its packer (or other sealing means) is unseated, to prevent any swabbing action as the sealing means is moved along the casing.

During the stage illustrated in FIG. **3** as well as during the stage shown in FIG. **2,** any fluid that is injected or produced flows selectively through either the perforation **14** or the perforation **12.** Because of this, the permeability of the perforation at such locations can be measured and, if desired, perforation cleaning or re-perforating measures, or the like, can be employed to ensure the existence of good fluid communication with the reservoir formation at each depth location. In addition, the permeability of the adjacent portions of the reservoir formation can be similarly measured and, if desired, adjusted. For example, measurements of the portion of the reservoir adjacent to perforation **14** may indicate a permeability and/or a degree of consolidation that is undesirably low, relative to that exhibited by the portion of the reservoir adjacent to perforation **12,** or relative to a similarly located portion of the same reservoir that has been encountered in an adjacent well, or the like.

As indicated in FIG. **3,** the portion of the reservoir near perforation **14** can be individually treated. Dashed lines **16, 17,** and **18,** represent the frontal portions of slugs of, respectively, an acidizing fluid, a buffer fluid, and a sand-consolidating fluid, that have been injected through perforation **14** in order to increase both the permeability and the degree of consolidation of the earth formation in the vicinity of that perforation. As indicated, this can be done without affecting the properties of the earth formation adjacent to the perforation **12.**

As will be apparent to those skilled in the art, numerous variations can be made in the particular types of equipment and sequences of operations utilized in practicing this invention. For example, where desirable, in the stage shown in FIG. **3,** the sealing means **7** and **8,** could be actuated to open the seals and permit a circulation of a different fluid into the depth interval being perforated. Alternatively, if perforation debris and/or reservoir sand inflows during a backflushing of the perforation **14** it can be removed with the seals formed by means **7** and **8** left intact. In the latter type of operation, continuous tubing, or the like, can be inserted through the conduit **4** and utilized to remove the sand-laden portion of fluid below the seal of means **8** while displacing in a clean batch of the same fluid, or a different fluid. By utilizing such a tubing insertion and fluid circulation, the fluid in the portion of casing in which perforation **12** is formed can be replaced by a different fluid that is circulated into the portion of casing in which perforation **14** is to be formed, etc. —while maintaining a pressure equalling the formation fluid pressure in the fluid adjacent to each open perforation.

What is claimed is:

1. A process for forming and individually treating perforations at different depths within a depth interval to be perforated in a cased well, which process comprises:

positioning a conduit within the well casing and displacing a fluid of selected composition into the passageway between the conduit and the casing within the depth interval to be perforated;

above the depth interval to be perforated, sealing the passageway between the conduit and the casing with a slidable mechanical seal that is located above the lower end portion of the conduit and is adapted to maintain said seal around the conduit while the conduit is moved to adjust the position of its lower end;

while maintaining said slidable seal, moving the conduit to the extent required to position its lower end above the top depth to be perforated;

mechanically sealing the passageway around the lower end of the conduit, between the lower end portion of the conduit and the adjacent portion of casing;

while maintaining said seal around the lower end of the conduit, operating a perforating device and a fluid circulating device to form and fluid-treat at least one perforation at substantially the top depth to be perforated; and

moving the conduit, sealing the passageway around the lower end of the conduit, and maintaining such a seal while operating a perforating device and fluid-circulating means, at least one additional time, in order to form and treat at least one perforation at a different depth within the same depth interval.

2. The process of claim **1** in which said fluid of selected composition is displaced into substantially all of said passageway between the conduit and casing below the depth of said slidable seal.

3. The process of claim **1** in which said fluid of selected composition is a brine.

4. The process of claim **1** in which the pressure of the fluid within the casing in the depth interval to be perforated is adjusted to be substantially equal to the earth formation fluid pressure in that depth interval.

5. The process of claim **1** in which the density of said fluid of selected composition and the density of the fluid that is circulated to effect said perforation fluid-treatment are adjusted to the extent required to provide densities that are substantially equal.

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