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EROSION PROTECTION FOR WELLS

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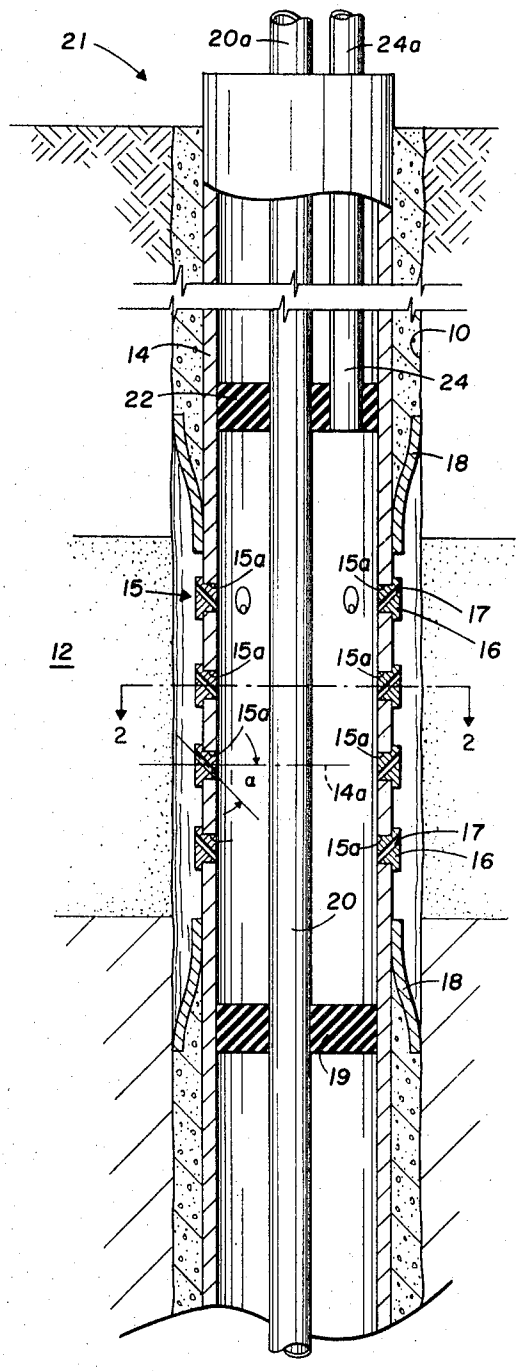


FIG. 1

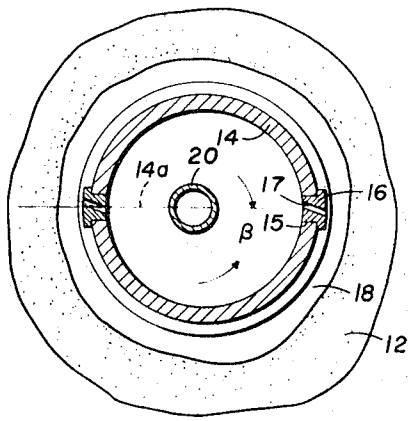


FIG. 2

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EROSION PROTECTION FOR WELLS

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ABSTRACT OF THE DISCLOSURE

Apparatus for protecting the surface of a tubing carrying fluid from a lower formation in a multiple completed well from the erosive effects of a fluid entering the well from a higher formation including a casing having a plurality of ports in the wall thereof adjacent the higher formation. Each port is comprised of an opening in the casing in which a plug means is fitted. The plug means is of erosive-resistant material and has a passage therethrough which is diverted at a skew angle with respect to the casing radius. By so diverting the passages, fluid entering the well will be diverted up or down and away from the tubing.

BACKGROUND OF THE INVENTION

In the petroleum industry, downhole well equipment often is subjected to erosion due to the abrasive action of detrital material such as unconsolidated sand grains entrained in the petroleum fluids as they enter the well. This problem most often is encountered in multiple completed wells which produce fluids from two or more levels in a well. The most common multiple completed wells are dual-completion wells in which oil and/or gas are produced from two vertically spaced, subterranean formations. A conventional manner of dually producing such formations is to set and cement casing through both formations and then set a casing packer between the formations. A tubing string is extended through the packer with its lower open end landed adjacent the lower productive formation. The casing packer thus effectively seals off the annular space between the tubing and casing and isolates the lower formation, which is in fluid communication with the interior of the tubing string. The fluid from the lower formation thus flows through the tubing and to the surface of the well or welhead separately from the fluid from the upper formation which is produced through perforations in the casing into the annulus between the casing and the tubing string. The fluid from the upper formation flows to the wellhead either directly through the annulus or through an additional tubing string.

In such wells a section of pipe, such as the well tubing mentioned above, extends past the upper productive formation and is exposed to the produced fluid from the upper formation as it enters the well through the perforations in the wall of the casing. This fluid usually is under substantial pressure and passes from the upper productive formation through the restricted perforations in the casing at a high velocity and in jetted streams. This is particularly true where the fluid being produced is comprised primarily of gas. Such fluid often has a content of sand or other particulate, detrital material which directly impinges against the tubing surface adjacent the perforations. Such detrital material entrained in the incoming fluid abrades and erodes the tubing surfaces, thus leading to tubing failure and also intensifying the corrosion of the tubing.

In the past, numerous means have been employed in attempts to protect tubing surfaces and alleviate the erosion thereof. One technique involves the wrapping of layers of lead around the tubing on the theory that a

malleable material would absorb some of the kinetic energy of the detrital material more readily than the tubing itself. Alternately, hard, brittle material, such as ceramics and glass, and resilient materials, such as rubber, have been employed as protective material for the tubing. While such techniques have met with some success—the resilient coating usually being the most effective—none of these techniques has proven entirely satisfactory.

One difficulty experienced with the heretofore practiced procedures resides in the fact that the materials used, even though sometimes more resilient to the brasive action of the detrital material than the metal pipe surfaces, still experience some erosion and ultimately fail, leaving the pipe surfaces exposed. This, of course, necessitates expensive workovers, such as withdrawing the tubing, repairing it if necessary, and providing additional protective material.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided new and improved apparatus for alleviating erosion of downhole well equipment, such as well tubing which does not require the deposition of protective members between the casing perforations and the surface within the interior of the casing which is to be protected from erosion. In carrying out the present invention, there is provided a well traversing a subterranean productive formation from which it is desired to recover fluid, such as petroleum gas. The well has a first conduit or casing therein which in turn has a plurality of ports in the wall thereof which lie adjacent the productive formation and allow fluid from said formation to flow into the interior of the casing. These ports are diverted in both a relatively vertical and a relatively horizontal direction with respect to the radius of the casing so that fluid entering these ports will be directed up or down and away from direct impingement on the tubing to be protected. Although these ports could possibly be formed by perforating the casing in place so that the perforations themselves would be inclined in the desired direction, in the present invention they are preformed prior to running the casing into the well. This is done preferably by forming a plurality of openings in the wall of the casing and providing each opening with a plug means of erosion-resistant material. Each plug means has one or more passages therethrough with each passage being inclined at a skew angle with respect to the radius of the casing. Fluid entering the passages will be diverted up or down and away from the center of the casing in a swirling motion thereby preventing the fluid from directly impinging on any tubing positioned at that point. By preforming the passages in plugs of erosion-resistant material, erosion of said passages due to the erosive fluid flowing therethrough is alleviated. This allows the passages to maintain the desired angle of deviation even after long periods of production.

The actual construction, operation, and the apparent advantages of the invention will be better understood by referring to the drawings in which like numerals identify like parts and in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is an elevation partly in section of a well embodying the present invention; and

FIGURE 2 is a cross-sectional view taken along line 2—2 of FIGURE 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring more particularly to the figures, wellbore **10** traverses a productive formation **12** and is provided with

a first conduit or casing **14**. Casing **14** is provided with a plurality of ports **15** which lie adjacent productive formation **12** when casing **14** is in place in the well. Each port **15** is comprised of an opening **15***a* which is provided with a plug means **16** having a passage **17** therethrough. A more detailed description of the plug means follows below. Casing **14** is cemented in wellbore **10** in such a way that no cement will be between the productive formation **12** and casing **14** at the completion of the cementing operation. The actual method of cementing the casing **14** forms no part of the present invention and can be accomplished by any one of many known cementing processes. For example, casing **14** can be cemented in wellbore **10** by using a cement retainer in a "cementing-through-perforation" operation as shown in Petroleum Production Engineering, Uren, Exploitation, third edition, p. 445. Blocking means **18**, such as canvas baskets or the like, are secured to casing **14** at desired locations prior to the positioning of casing **14** in the well and serve to prevent cement from entering the space behind casing **14**, as is well known in the art.

A packer **19** is disposed between the productive formation **12** and a lower productive formation (not shown) in order to isolate these formations from one another and to prevent communication between these formations within the well. A second conduit or production tubing **20** of smaller diameter than casing **14** is disposed substantially concentrically in the well as illustrated and extends from wellhead **21** to a level (not shown) below the packer **19**, usually adjacent the lower productive formation. Fluids from the lower productive formation thus are produced through the interior of tubing **20** and are carried to the surface of the well where they pass into a suitable gathering line **20***a*. A second packer **22** is provided between tubing **20** and casing **14** at a point above the top of productive formation **12**. A second tubing **24** extends from the surface of the well and through second packer **22**, as shown. As is evident from the drawing, second tubing **24** provides a productive passage to the surface of the well or wellhead for fluids produced from productive formation **12**. At the wellhead, fluids from second tubing **24** are delivered into a gathering line **24***a*.

The production equipment positioned within casing **14** is conventional and does not by itself comprise the present invention. Also, it will be understood that the arrangement within casing **14** is exemplary only in that other suitable arrangements may be used. For example, second tubing **24** and second packer **22** may be dispensed with and fluids from productive formation **12** may be produced to the surface of the well directly through the annular space defined by tubing **20** and casing **14**. Alternatively, tubing **20** may not extend to the wellhead, but may instead terminate within or above second packer **22**, in which case fluid from the lower formation will pass from tubing **20** into the space between second tubing **24** and casing **14** and then upwardly to the wellhead. Also, while only a single string of casing **14** is shown, it will be understood that the well may be provided with a plurality of casing strings. For example, the well may be provided with a suitable conductor pipe or surface string and one or more intermediate strings as will be understood by those skilled in the art.

In accordance with the present invention, plug means **16** are formed of erosion-resistant material. This material is preferably a hard metal alloy having a hardness greater than the Rockwell *c* scale hardness (R*c*) of 60, e.g., nickel chromium. It can also be a plastic material, e.g., polypropylene, or synthetic rubber, or ceramic material. Erosion-resistant plugs **16** are press-fitted, cemented, welded, or otherwise secured in openings **15***a* in casing **14** prior to placement of the casing in the wellbore.

As stated above, each plug **16** has a passage **17** therethrough. Although plugs **16** are shown as having only one passage in each, it should be recognized that more than one passage could be provided in each plug, depending on the size of the plug and the diameter of the passages therein. Passages **17** through plugs **16** are diverted in both a relatively vertical and relatively horizontal direction with respect to casing radius **14***a* as clearly shown in the figures. In other words, passage **17** is inclined at a skew angle with respect to the radius of the casing. Passage **17** is diverted vertically with respect to radius **14***a* at an angle α and horizontally at an angle β. The angle α has been illustrated as a downward angle but it should be recognized that passages **17** could also be inclined upward at a similar angle without departing from the present invention. In order to decrease the erosive effects of the incoming fluid further, angle α should be greater than 45° so that the hypothetical angle of contact between the fluid and tubing **20** is less than the angle of reflection therefrom. Note that the fluid will not directly contact tubing **20** due to angle β discussed immediately following. Angle β depends on the size of casing **14** and tubing **20** and the exact placement of the tubing within the casing; but this angle should always be great enough to insure that fluid entering through passage **17** will be deflected laterally to an extent necessary to prevent the fluid from directly impinging on tubing **20** which is positioned substantially concentric within casing **14**. By so directing passage **17**, production fluid from formation **12** entering casing **14** through passages **17** will follow a spiral-like path upward or downward and away from tubing **20**, thereby imparting a swirling motion to the fluid and decreasing the erosive effects of the fluid when it finally does come into contact with tubing **20**. Fluid flowing through passages **17** has little erosive effect on the passages themselves since they are formed in erosive-resistant material. This allows the direction of passages **17** and hence the direction of the incoming fluid to remain substantially constant over long periods of production.

Although a particular embodiment of the present invention has been illustrated and described, the disclosure is intended to cover all changes and modifications therein which do not constitute departure from the spirit and scope of the invention.

What is claimed is:

1. In a well penetrating a productive formation and adapted for the production of fluids therefrom, apparatus for alleviating erosion of downhole equipment comprising:

a first conduit disposed in said well, said conduit having a plurality of ports through the wall thereof adjacent said production formation, each of said ports being preformed in said first conduit prior to being disposed in said well and comprising:

an opening in the wall of said first conduit, and plug means of erosion-resistant material positioned in said opening, said plug means having one or more passages therethrough, each passage being inclined at a skew angle with respect to the radius of said first conduit; and

a second conduit of a smaller diameter than said first conduit positioned substantially concentrically in said first conduit whereby fluid entering said first conduit through said passages will be directed away from direct impingement on said second conduit.

2. Apparatus for alleviating erosion of downhole equipment in accordance with claim **1** wherein:

said plug means of erosion-resistant material is comprised of a hard metal alloy having a hardness greater than the Rockwell *c* scale hardness of 60.

3. Apparatus for alleviating erosion of downhole equipment in accordance with claim **2** wherein:

said hard metal alloy is nickel chromium.

4. Apparatus for alleviating erosion of downhole equipment in accordance with claim **1** wherein:

said plug means of erosion-resistant material is comprised of ceramic material.

5. Apparatus for alleviating erosion of downhole equipment in accordance with claim 1 wherein:

said plug means of erosion-resistant material is comprised of polypropylene plastic.

6. Apparatus for alleviating erosion of downhole equipment in accordance with claim 1 wherein:

said plug means of erosion-resistant material is comprised of synthetic rubber.

7. In a well penetrating a productive formation and adapted for the production of fluids therefrom, apparatus for alleviating erosion of downhole equipment comprising:

a first conduit disposed in said well, said conduit having a plurality of ports through the wall thereof adjacent said productive formation, each of said ports being preformed in said conduit prior to said conduit being disposed in said well and comprising:

an opening in the wall of said first conduit, and plug means of erosion-resistant material positioned in said opening, said plug means having one or more passages therethrough, the axis of each passage being directed at a relative horizontal angle with respect to the radius of the first conduit; and

a second conduit of a smaller diameter than said first conduit positioned substantially concentrically in said first conduit whereby fluid entering said first conduit through said passages will be directed away from direct impingement on said second conduit.

8. Apparatus for alleviating erosion of downhole equipment in accordance with claim 7 wherein:

the axis of each of said passages in said plug means also being directed at a relative vertical angle with respect to the radius of said first conduit.

9. Apparatus for alleviating erosion of donwhole equipment in accordance with claim 8 wherein:

said relative vertical angle is greater than 45°.

10. Apparatus for alleviating erosion of downhole equipment in accordance with claim 7 wherein:

said plug means of erosion-resistant material is comprised of a hard metal alloy having a hardness greater than the Rockwell *c* scale hardness of 60.

11. In a well penetrating a productive formation and adapted for the production of fluids therefrom, apparatus for alleviating erosion of downhole equipment comprising:

a first conduit disposed in said well, said conduit having a plurality of preformed passages through the wall thereof adjacent said productive formation, the axis of each of said passages being directed at a skew angle with respect to the radius of said first conduit; and

a second conduit of a smaller diameter than said first conduit positioned substantially concentrically in said first conduit whereby fluid entering said first conduit through said passages will be directed away from direct impingement on said second conduit.

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