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EROSION PROTECTION FOR WELLS

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FIG. 1

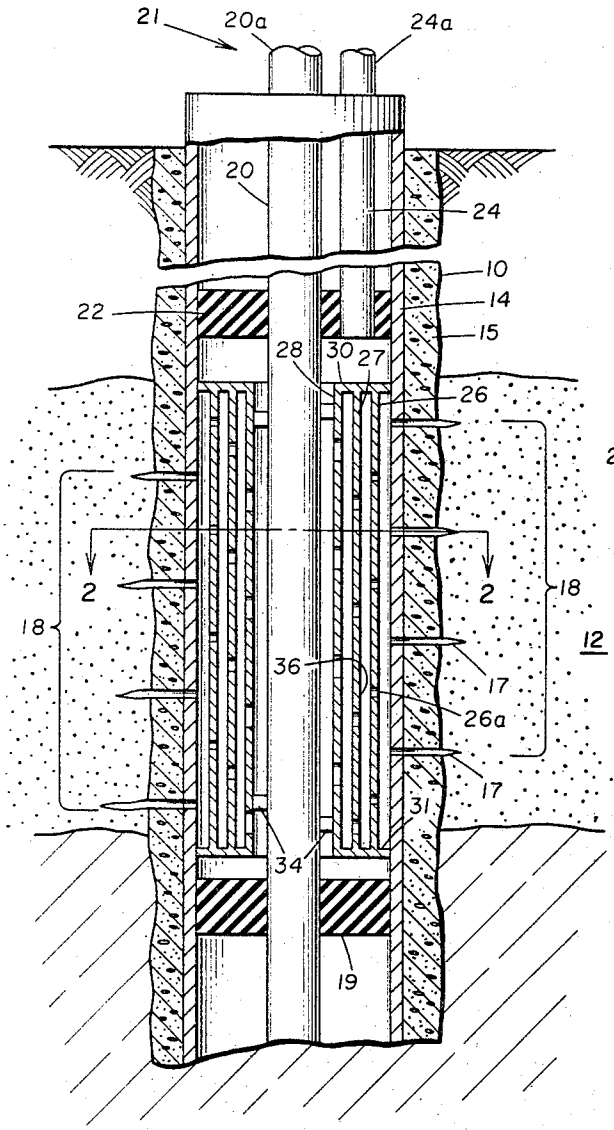
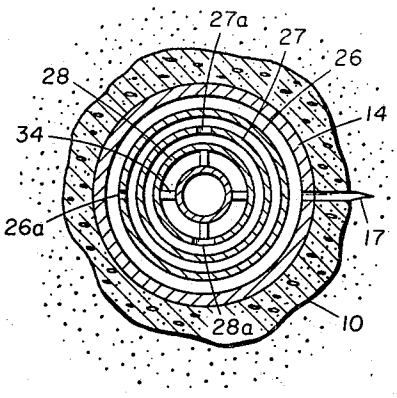


FIG. 2



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EROSION PROTECTION FOR WELLS

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ABSTRACT OF THE DISCLOSURE

A system used in a multi-ply completed well for protecting a tubing which carries a fluid from a lower production formation against the erosive effects of a fluid from a higher production formation as the erosive fluid enters the well under high pressure through perforations in the well casing. The system comprises a plurality of baffle sleeves concentrically mounted about the tubing in the area of the higher production formation. Each of the sleeves has perforations which are staggered in relation to perforations in the next adjacent sleeve so that the erosive fluid entering the well is forced to follow a tortuous flow path before it impinges on the tubing. This changing flow path causes the erosive fluid to decrease its kinetic energy and reduce its impact velocity before it reaches the tubing, thereby reducing erosion of the tubing and increasing the life thereof.

This invention relates to the production of subterranean fluids through wells, and more particularly to a system for alleviating erosion of downhole well equipment by detrital material contained in such subterranean fluids.

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 petroleum fluids as they enter the well. This problem most often is encountered in multi-ply completed wells which produce fluids from two or more levels in a well. The most common multi-ply completed wells are dual-completion wells in which oil or gas is 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 wellhead 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.

The section of well tubing which extends past the upper productive formation is exposed to the produced subterranean fluid as it enters the well through perforations in the wall of the casing. The fluid usually is under substantial pressure and passes from the productive formation through the restricted perforations in the casing at high velocity and in jetted streams. This particularly is 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 impinges against the pipe surface adjacent the perforations. Such detrital material entrained in the incoming fluid abrades and erodes the pipe surface, thus leading to pipe failure, and also intensifying the corrosion of the pipe.

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. Alternatively, hard, brittle material such as ceramics and glass and resilient materials such as rubber have been employed as protective materials for the tubing. While such techniques have met with some success, the resilient coatings usually being the most effective, none of these techniques has proven entirely satisfactory.

In accordance with the present invention, there is provided a new and improved system for alleviating erosion of downhole well equipment such as tubing string. A preferred embodiment of the invention is utilized in a well traversing a subterranean formation from which it is desired to recover fluids such as petroleum gases. The well has a first conduit therein with a perforated interval comprising a plurality of perforations in the wall thereof. The perforated interval is located opposite a subterranean producing formation such as the upper formation in a dually completed well of the type described above. A second conduit such as a tubing string is disposed within the first conduit opposite the perforated interval. In producing the well, fluid normally is flowed through the perforated interval in the first conduit and then upwardly within the first conduit to the surface of the well. Thus, the outer surface of the second conduit is subject to abrasive action of detrital material entrained in the production fluids.

In carrying out the instant invention, a plurality of laterally spaced baffle members are interposed between the perforated interval in the first conduit and the outer surface of the second conduit. In a preferred form of the invention, the baffle members take the form of a plurality of tubular sleeves extending about the outer perimeter of the second conduit. Regardless of the configuration of the baffle members, each baffle member is provided with perforations therein which are staggered relative to the perforations in the next adjacent of the baffle members. Thus, the baffle members serve to change the direction of flow of the production fluids and detrital material entrained therein. Also, the flow of the jet streams emanating from the perforations in the first conduit are changed from streamline or laminar flow to turbulent flow and the pressure drop between the casing and the outer surface of the production tubing is decreased as the production fluids pass through the several baffle members. These factors tend to decrease the kinetic energy of the detrital material entrained in the production fluids and reduce the velocity of impact thereof on the surface of the production tubing.

For a better understanding of the present invention, reference may be had to the following detailed description taken in conjunction with the accompanying drawings in which:

FIGURE 1 is an elevation partly in section of a production well assembly embodying a preferred form of the invention; and

FIGURE 2 is a horizontal section taken on line 2—2 of FIGURE 1.

With reference to FIGURE 1, there is shown a wellbore **10** traversing a productive formation **12** and provided with a first conduit or a casing string **14**. The casing is cemented as indicated at **15** and the casing and surrounding cement sheath are provided with a plurality of perforations **17** which define a perforated interval in the casing as indicated by brackets **18**. Although in most wells in which the present invention is utilized the perforations **17** will take the form of generally circular

passages such as those formed by jet or gun-perforating techniques, it will be understood that other suitable arrangements may be used. For example, the perforated interval may be formed by so-called "shop perforated" or slotted pipe in which the openings in the casing are formed prior to insertion of the casing in the well.

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 so that there is no communication between these formations within the well. A production tubing string **20** is disposed in the well as illustrated and extends from the wellhead **21** and is landed at a level (not shown) below the packer **19**, usually adjacent the lower productive formation. Fluids from the lower porductive formation thus are produced through the interior of the tubing string **20** and carried to the surface of the well where they pass into a suitable gathering line **20***a*.

A second packer **22** is provided between the tubing string **20** and casing **14** at a point above the top of the productive formation **12**. A second tubing string **24** extends from the surface of the well and through the second packer **22** as shown. As is apparent from the drawing, the second tubing string **24** provides a production passage to the surface of the well for fluids produced from the productive formation **12**. At the wellhead, fluids from tubing string **24** are delivered into gathering line **24***a*.

The production equipment thus far described is conventional and does not by itself form any part of the present invention. Also, it will be understood that the arrangement thus far described is exemplary only and that other suitable arrangements may be used. For example, tubing **24** and packer **22** may be dispensed with and fluids from the productive formation **12** may be produced to the surface of the well directly through the annular space between the tubing **20** and the casing **14**. Alternatively, tubing string **20** may not extend to the wellhead, but instead may terminate within or above packer **22**, in which case fluid from the lower formation will pass from tubing **20** into the space between tubing **24** and casing **14** and thence upwardly to the wellhead. Also, while only a single casing string **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 addition, while the casing **14** in FIGURE 1 is shown as extending completely to the surface of the well, it will be understood that other suitable arrangements may be used. For example, the perforated outer conduit may take the form of a liner which is suspended from or otherwise extends into a casing string. Alternatively, the perforated conduit may take the form of a so-called "scab liner" which does not extend up into a casing string but simply rests upon the bottom of the borehole and is cemented therein in accordance with conventional practices. In this case all or part of the well above the perforated liner may be encased. Such completion practices are well known to those skilled in the art and therefore will not be described further.

In accordance with the instant invention, there is provided in the annulus between the outer surface of tubing **20** and the perforations **17** in casing **14** at least two and preferably at least three laterally spaced baffle members. As shown most clearly in FIGURE 2, the baffle members preferably take the form of tubular sleeves **26**, **27**, and **28** disposed in nesting relationship with one another and mounted concentrically about the outer surface of tubing **20**.

The sleeves **26**, **27**, and **28** are held in spaced-apart relationship by means of upper and lower plates **30** and **31**. Preferably the upper and lower plates are formed integrally as shown in order to form a rigid assembly. This assembly is spaced from the tubing **20** by means of spacing members such as are shown at **34** in the drawing. Each of the sleeves **26**, **27**, and **28** is provided with perforations **26***a*, **27***a*, **28***a*, respectively, which are staggered relative to the perforations in the next adjacent sleeve or sleeves so that a straight line cannot be drawn through any two perforations in adjacent sleeves intersecting the surface of the next inner member at right angles. Thus, fluid emanating from the perforation in one sleeve will impinge against a blank portion of the next adjacent inner sleeve and fluid flowing into the well through perforations **17** must follow a tortuous path before it reaches the outer surface of the tubbing string **20**. Therefore, any abrasive detrital material which contacts the outer surface of the tubing string **20** does so at a relativvely low kinetic energy state, thus causing little if any erosion of the outer tubing surface.

Preferably, the perforations in any given sleeve are staggered relative to the perforations in all the remaining sleeves as shown in the drawing. Thus, even though the abrasive action of the incoming detrital material should erode an opening in one of the outer sleeves **26** or **27**, this opening still would be in a staggered relationship with the perforations in the next adjacent inner sleeve. For example, it can be seen from an examination of FIGURE 1 that detrital material entrained in fluid passing through one of perforations **26***a* in sleeve **26** and impinging upon the area of sleeve **27** generally indicated by reference numeral **36** ultimately may erode an opening in this sleeve. However, the opening thus formed would still be staggered with regard to the perforations in the next adjacent inner sleeve **28**. Also, the formation of such an opening due to the abrasive action of the detrital material will in many cases serve to increase further the turbulent flow of the production fluids within the annulus between casing **14** and tubing **20**, thus serving to decrease further the kinetic energy of the detrital material entrained therein.

In the drawings, the perforations in the outer baffle member **26** are shown staggered relative to the perforations in the casing or outer conduit **14**. While this arrangement is preferred, it is often difficult, if not impossible, to achieve due to the difficulties involved in determining accurately the locations of the perforations **17** and in positioning the baffle member. Thus, even though an attempt is made to position the outer baffle member as shown in the drawing, it is likely that some of the perforations therein may be located opposite the casing perforations. In this case, the remaining baffle or baffles interposed between the outer baffle and the tubing are essential to the provision of a tortuous flow path between the casing perforations and the outer surface of the tubing. As noted above, the preferred embodiment of the invention comprises three or more baffle members. However, in some well installations, space limitations may be such that only two baffle members can be interposed between the tubing and casing. In any case, at least two baffle members must be utilized in order to achieve the new and improved results of the instant invention.

In a preferred embodiment of the invention, the total cumulative cross-sectional area of the perforations in each of the baffle members is increased with the proximity of the baffle member to the inner tubing **20**. Thus, the total perforation area in baffle member **28** is greater than the perforation area in baffle member **27** which in turn is greater than the perforation area in baffle member **26**, etc. This may be accomplished by the provision of perforations of progressively greater diameter as shown in the drawings and/or the provision of increasingly greater numbers of perforations. That is, baffle member **28** may be provided with more perforations than baffle member **27**, etc. This feature of the invention tends to equalize the pressure drop between adjacent baffle members and between the outermost baffle member and the casing. Preferably, the total cumulative cross-sectional area of the perforations in any given baffle member is about twice

the area of the perforations in the next adjacent outer baffle member. Thus, the total cross-sectional area of the perforations in baffle member **27** will be approximately twice that of the perforations in baffle member **26**. This same relationship also preferably holds true with regard to the perforations in the outermost baffle member and the perforations in the casing. That is, the total area of the perforations in baffle member **26** should be greater than and preferably about twice the area of the perforations **17** in casing **14**.

The upper and lower plate members **30** and **31** (FIGURE 1) preferably provide complete closures for the spaces between adjacent baffle members and the space between the outermost baffle member and the casing **14**. Thus, all of the fluid flowing into the well must traverse each baffle member. The provision of such closure members at the upper and lower ends of the baffle members insures against the possibility of some detrital material contacting well equipment such as packer **22** at a relatively high kinetic energy state.

The baffle members may be rigidly mounted on the tubing. For example, the spacing elements **34** may be welded or otherwise secured to the outer surface of the tubing. In this case, of course, it will be necessary to install and remove the baffle members as a unit with the tubing string. In some instances, it may be desirable to slidably mount the baffle members about the outer surface of the tubing **20** and support it on a suitable support member such as packer **19** shown in FIGURE 1. In a well installation in which equipment such as packer **22** and tubing **24** is not present, this feature is particularly advantageous in that the baffle members may be installed or withdrawn without running or pulling the tubing string. Thus, as one baffle assembly is depleted it may be withdrawn from the well by means of suitable wire line apparatus and another assembly installed simply by lowering it through the annulus between the tubing and casing.

Having described certain specific embodiments of the instant invention, it will be understood that further modifications thereof may be suggested to those skilled in the art, and it is intended to cover all such modifications as fall within the scope of the appended claims.

What is claimed is:

1. In a well traversing several formations and adapted for the production of subterranean fluids, a system for alleviating erosion of downhole equipment, comprising:

a first conduit disposed in said well, said first conduit having a perforated interval adjacent one of said formations comprising a plurality of perforations in the wall of said first conduit adapted for the passage of subterranean fluids into the interior of said first conduit;

sealing means positioned within said first conduit below said perforated interval to isolate said perforated interval from other of said formations below said perforated interval;

a second conduit of a smaller size than said first conduit disposed within said first conduit, said second conduit extending from said sealing means to a point above said perforated interval to establish a closed flow path through said perforated interval; and

a plurality of laterally spaced baffle members interposed between said perforated interval in said first conduit and the outer surface of said second conduit, each of said baffle members having perforations therein which are staggered relative to the perforations in the next adjacent of said baffle members.

2. The system of claim **1** comprising at least three of said baffle members.

3. The system of claim **1** wherein the perforations in the baffle member next adjacent said first conduit are staggered relative to the perforations in said first conduit.

4. The system of claim **1** wherein said baffle members comprise tubular sleeves extending about the outer perimeter of said second conduit, said sleeves being of different sizes and disposed in nesting relationship with one another.

5. The system of claim **4** wherein the total cumulative cross-sectional area of the perforations in each of said sleeves increases with the proximity of said each of said sleeves to said second conduit.

6. The system of claim **4** comprising at least three of said tubular sleeves.

7. The system of claim **6** wherein the perforations in the outermost tubular sleeve next adjacent said first conduit are staggered relative to the perforations in said first conduit.

8. The system of claim **7** wherein said tubular sleeves are slidably mounted on said second conduit.

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