Aug. 12, 1969 H. L. EHRLICH 3,460,626

METHOD AND APPARATUS FOR ALLEVIATING EROSION IN MULTIPLE-COMPLETION WELLS

Filed March 31, 1967 2 Sheets-Sheet 1

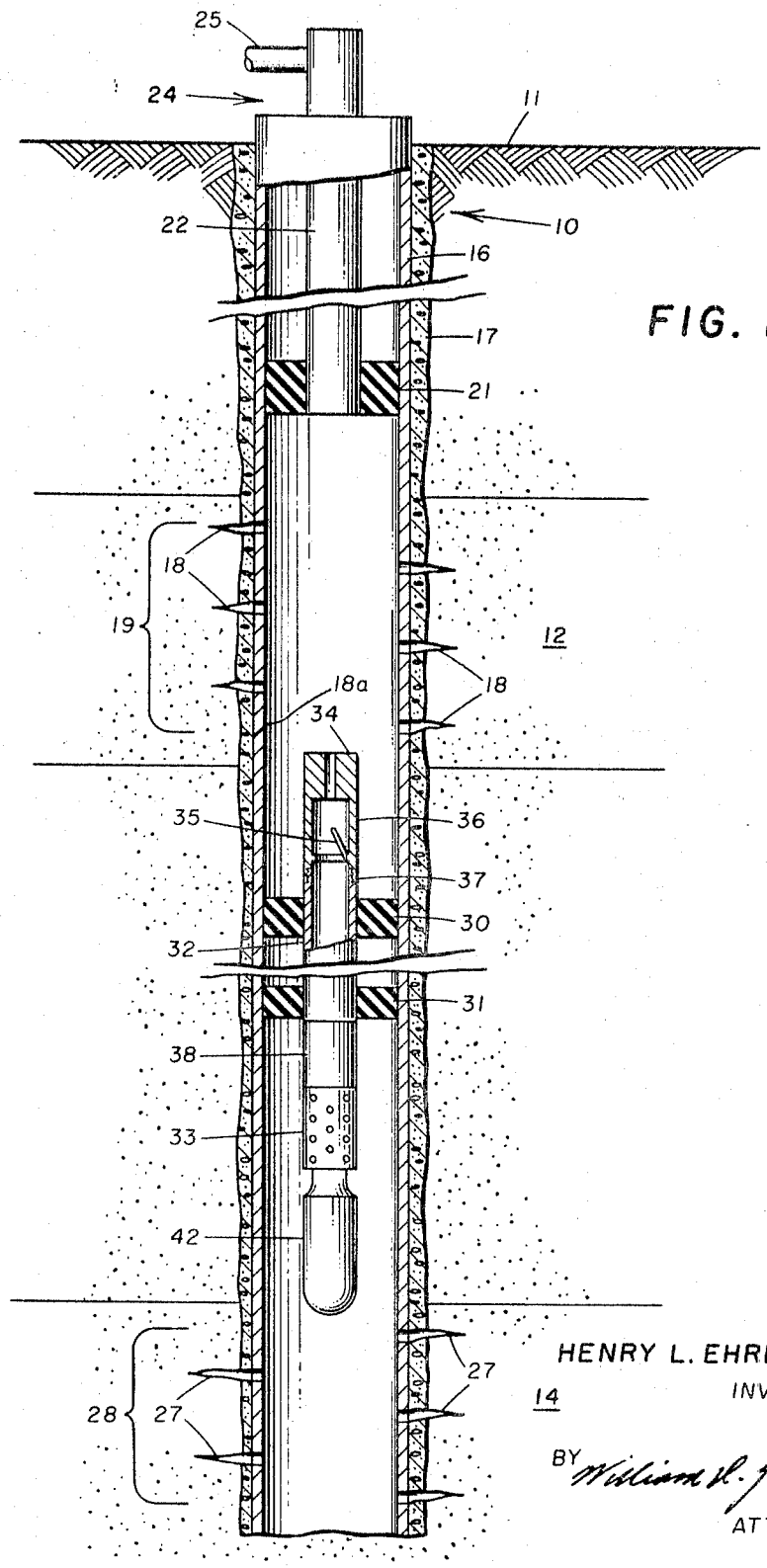


FIG. 1

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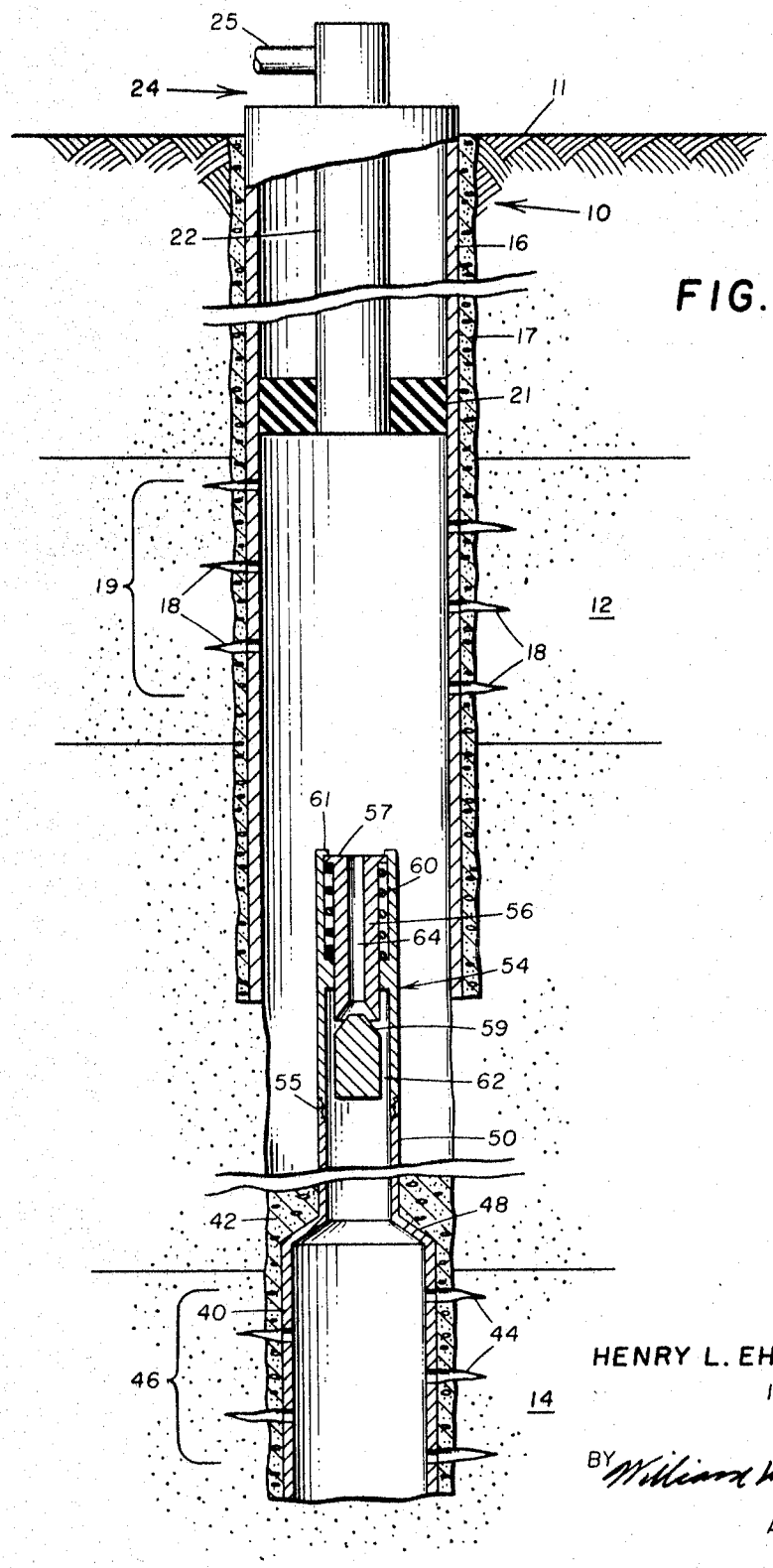


FIG. 2

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METHOD AND APPARATUS FOR ALLEVIATING EROSION IN MULTIPLE-COMPLETION WELLS

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U.S. Cl. 166—313 9 Claims

ABSTRACT OF THE DISCLOSURE

This disclosure describes a well installation and method for use in multiple-completed wells subject to "blast-zone" erosion. A packer is disposed within a well between upper and lower production intervals thereof. A conduit extends through the packer and terminates below the top of the upper production interval. This conduit provides for fluid communication between the upper and lower intervals. The conduit is provided with a flow-restricting device which reduces the pressure of the fluid flowing upwardly through the conduit.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to the production of subterranean fluids through wells, and more particularly to well installations and methods for alleviating erosion of downho'e well equipment by detrital material contained in su h subterranean fluids.

Description of the prior art

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 is most often encountered in multiple-completed wells which produce fluids from two or more levels in a well. The most common multiple-completed wells are those in which oil and/or gas is produced from two or more vertically spaced subterranean formations. Such formations may be separate lithologic units or they may be different zones of a common reservoir which are separated by relatively continuous strata of impermeable rock such as shale.

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, from the upper formation. The fluid from the lower formation thus flows through the tubing 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.

Another form of multiple-completed well is somewhat similar to that described above except that the fluids from the two or more formations involved are produced through the tubing string. In this arrangement, the tubing string normally extends past the upper formation and through a packer as described above. The tubing string is provided with a commingling tool, normally positioned in the vicinity of the upper productive formation, which

commingles the fluids from the upper and lower formations. The commingled fluids then are withdrawn to the surface of the well through the tubing string.

In each of the above-described forms of multiple-completions, a section of pipe, such as well tubing, extends past a productive formation and thus 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 velocities and in jetted flow courses. 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 conventional techniques have been employed in attempts to protect tubing surfaces and to prevent erosion thereof. Typically, these techniques involve the provision of so-called "blast-zone protectors" about the tubing adjacent the upper formation. Blast-zone protectors may be utilized in well installations providing for commingled production, such as disclosed in U.S. Patent No. 3,283,570 to J. W. Hodges, or in well installations providing for separate production, such as disclosed in U.S. Patent No. 3,294,122 to L. G. Sharp. Such blast-zone protectors may take numerous forms. One means proposed for providing blast-zone protection involves wrapping of layers of lead around the tubing on the theory that a malleable material will absorb some of the kinetic energy and the detrital material more readily than the tubing itself. Alternatively, hard brittle materials, 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.

One difficulty experienced with the heretofore proposed procedures resides in the fact that the materials used in forming the blast-zone protectors, even though they are sometimes more resistant to the abrasive action of the detrital materials than the metal pipe surfaces, still experience some erosion and ultimately fail; thus leaving the pipe surfaces exposed to the abrasive action of detrital materials as they enter the well. If this condition is undetected the exposed surfaces may fail under the erosive action of such materials, sometimes within a matter of hours. This, of course, necessitates expensive workovers such as withdrawing the tubing, repairing it if necessary, and providing additional protective material. Another serious consequence of such failure is the placing of the respective formations directly in communication with one another through the well. In this case, production may be obtained only from the formation of relatively high pressure and fluid from the relatively high pressure formation may flow into the lower pressure formation. This latter situation may result in severe damage to the lower pressure formation and, in addition, the fluid may be lost through this formation to other wells.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a multiple-completion well installation and method in which downhole well equipment, such as a tubing string, need not be located within a blast-zone area where it is subject to erosion. The method of the invention is practiced in a well penetrating at least two vertically

spaced subterranean formations in which the pressure of the lower formation is greater than the pressure of the upper formation. The well is open to the lower formation through a first production interval and to the upper formation through a second production interval which comprises a section of perforated casing. In carrying out the method of the invention, fluids from the lower and upper formations are produced into the well through the first and second production intervals, respectively. As the fluid from the lower formation enters the well it is passed through a flow path within the well which extends from the first production interval to the second production interval. As the lower formation fluid is passed to the second production interval, the pressure of the lower formation fluid is reduced to a value less than the upper formation pressure. The lower formation fluid is commingled within the second production interval with the fluid from the upper formation by contacting this latter fluid as it flows into the well through the casing perforations with the lower formation fluid. The commingled fluids then are withdrawn from the well.

In accordance with a preferred embodiment of the invention, there is provided a well installation which may be utilized in practicing the above-described method. This installation includes packing means disposed within the well to separate the upper and lower production intervals of the well. The packing means may be one or more conventional casing packers. A conduit extends upwardly through the packing means and terminates at a level below the top of the second or upper production interval. This conduit provides a passageway for the flow of fluid from the lower formation to the upper production interval. As the lower formation fluid flows into the second production interval, it is commingled with the fluid recovered from the upper formation. The conduit is provided with flow-restricting means which reduces the pressure of the lower formation fluid as it passes upwardly through the conduit.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is an illustration, partly in section, showing one embodiment of the present invention; and

FIGURE 2 is an illustration, partly in section, showing a modified embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIGURE 1, there is shown a wellbore **10** which extends from the surface **11** of the earth and penetrates vertically spaced subterranean formations **12** and **14**. The well is provided with a casing **16** which is cemented as indicated by reference numeral **17**. The casing and the surrounding cement sheath are provided opposite the formation **12** with a plurality of perforations **18** which define an upper production interval of the well, as indicated by bracket **19**. In most instances, the production interval **19** will be formed by a plurality of circular perforations produced by a jet or gun perforating technique. It will be understood, however, that other suitable arrangements may be used. For example, the production interval **19** may be formed by so-called "shop perforated" or slotted pipe in which openings are formed prior to insertion of the casing into the well. Numerous other procedures for providing an opening in a well to the flow of subterranean fluids are well known to those skilled in the art and, accordingly, will not be described further.

A packer **21** is disposed in the well above the top of the upper production interval **19**. The well also is provided with a tubing string **22** which extends from the wellhead **24** or surface of the well through the packer **21** to a level above the top of the upper production interval **19**. Fluids from the upper formation **12** and, as explained hereinafter, from the lower formation **14** are produced through the interior of the tubing string **22** and carried to the surface of the well where they are passed into a suitable gathering line **25**.

The casing **16** and surrounding cement **17** are provided opposite the lower formation **14** with a group of perforations **27** which define a lower production interval as indicated by bracket **28**. The lower production interval may be formed by other means as will be apparent to those skilled in the art.

The production equipment thus far described is exemplary only and it is to be understood that other suitable arrangements consistent with the practice of the present invention may be used. For example, the packer **21** and tubing string **22** may be dispensed with and fluids may be produced to the surface of the well directly through the casing **16**. Alternatively, tubing string **22** may not extend to the wellhead but instead may terminate within or above packer **21**, in which case fluid will likewise be recovered or produced from the well through the casing **16**. It usually will be preferred to extend tubing **22** to the surface as shown for reasons of well control and manipulation and also to avoid corrosion in the upper portions of the casing string.

It further is to be understood that, while only a single casing string **16** is shown, the well may be provided with a plurality of casing strings. For example, the well may be provided with a conductor pipe or surface string and one or more intermediate strings, as will be readily apparent to those skilled in the art. In addition, while the casing string **16** 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 casing adjacent the formation **12** and/or the formation **14** may take the form of a so-called "scab liner." Such a liner or liners may occupy only selected portions of the well, such as opposite formations **12** and **14**, in which case remaining portions of the well may be uncased. Further, in certain circumstances such as where the formation **14** is not subject to sand problems, the lower completion interval may be an open hole. In this case, the casing string **16** may be set into the top of the formation **14** and cemented in the well, and the well then drilled deeper to provide an open hole completion. These and other completion procedures are well known to those skilled in the art and, accordingly, will not be discussed further.

As is known by those skilled in the art, the pressures of subterranean formations normally increase with their depths. For example, an oil and/or gas reservoir found at a depth of 5,000 feet typically may exhibit a pressure on the order of 2,000 p.s.i., whereas, a deeper underlying reservoir found at 10,000 feet may be expected to be at a pressure on the order of 4,000 p.s.i. In the method of the present invention, this normal order of pressure relationships is utilized to advantage in a method of recovering fluids through a multiple-completion well. Therefore, for the purpose of describing this method it will be assumed that the pressure of formation **14** shown in FIGURE 1 is greater than the pressure of formation **12**.

It will be recognized by those skilled in the art, that by reference to the pressure of a designated formation or by the term "formation pressure," is meant the pressure of the formation adjacent the well under static conditions. This pressure may be determined for a given formation by conventional techniques. For example, the pressure of a formation in the vicinity of a well may be determined by a so-called "pressure build-up test" in which the well is shut in for such time as is necessary to establish a pressure equilibrium or near pressure equilibrium between the well and the formation. The static downhole pressure of the well when it is shut in with respect to the formation, i.e., when there is no fluid flow from the formation into the well, is, of course, substantially equivalent to the formation pressure.

It further will be recognized that the flow of fluids into the well depends upon an established differential between the pressure within the formation penetrated by the well and the downhole pressure within the well opposite the

formation. The downhole pressure of the well at any given rate of production is designated as the "operating pressure" of the well for this production rate and formation. The operating pressure of the well for a designated formation may, of course, vary widely depending upon the conditions under which the well is operated.

Returning now to FIGURE 1, the well is provided with packing means which separates the upper and lower production intervals **19** and **28**, respectively. As shown in FIGURE 1, this packing means may take the form of a pair of conventional casing packers **30** and **31**. Extending through the packers **30** and **31** is a conduit **32** which provides a passageway for the flow of fluid recovered from the lower formation **14** upwardly to the upper production interval **19** of the well. The conduit **32** include, in addition to certain instrumentalities described hereinafter, a perforated section **33** which provides for the entry of the lower formation fluid into the conduit.

It will be recognized that considerable distance may separate formations **12** and **14** and it usually will be desirable to utilize a plurality of packers as shown. This will aid in centering the conduit **32** within the well and also will prevent the casing between these packers from being contacted by well fluids, thus lessening corrosion problems within this area. However, the packing means may take another suitable form such as a single casing packer. Also, while the conduit **32** usually will comprise a tubing string, those skilled in the art will recognize that the conduit may comprise any suitable structure. For example, in appropriate circumstances the conduit may consist simply of the bore of a conventional packer.

As noted previously, the pressure of formation **14** is greater than the pressure of formation **12**. By way of example, formation **12** may be a gas reservoir at a depth of 5,000 feet exhibiting a formation pressure of about 2,000 p.s.i. and formation **14** may be a gas reservoir at a depth of about 10,000 feet and having a formation pressure of about 4,000 p.s.i. In view of these pressure relationships the conduit **32** is provided with flow-restricting means in order to reduce the pressure of the lower formation fluid as it passes from the lower production interval **28** of the well upwardly through the conduit **32** to the upper production interval **19**. Desirably, the pressure of the lower formation fluid is reduced to a value such that it is approximately equal to the desired operating downhole pressure within the upper production interval **19**. Thus, if it is desired to produce the formation **12** under a flowing pressure gradient from the formation to the well of 1,000 p.s.i., such that the operating downhole pressure within the interval **19** is 1,000 p.s.i., the flow of the lower formation fluid through the conduit **32** is restricted such that it exits from the conduit against a back pressure of about 1,000 p.s.i. It is recognized that under practical operating conditions it may be difficult to achieve such a pressure reduction within closely defined limits of accuracy. However, the pressure of the lower formation fluid should at least be reduced to a value such that it enters the upper production interval against a back pressure less than the pressure of the formation **12**, i.e., 2,000 p.s.i., in the example given above. If the pressure is not reduced to at least this level there exists the possibility of the fluid from the lower formation flowing into the upper formation **12** with the attendant deleterious results noted above.

While the flowing pressure gradient from the formation **12** into the well may vary widely depending upon local conditions, it usually will be desirable to produce the formation **12** under a pressure gradient of at least 2000 p.s.i. or 10% of the formation pressure, whichever is greater. Therefore, it is preferred in carrying out the invention to reduce the pressure of the lower formation fluid to a value which is less than the pressure of formation **12** by at least the greater of 200 p.s.i. and 10% of the pressure of formation **12**.

Pressure reduction within the conduit **32** may be accomplished by means of any suitable flow-restricting device. Thus, as shown in FIGURE 1, the conduit **32** is provided with a conventional downhole choke **34**. The size of the choke **34** may be selected in accordance with practices well known to those skilled in the art in order to achieve the desired pressure gradient thereacross. The pressure reduction to be achieved across the choke **34** will, of course, depend upon the frictional losses occurring in flow from the lower production interval upwardly through the conduit **32** to the choke **34**. Thus, if a total pressure reduction of 2,500 p.s.i. is desired between the upper and lower production intervals and the frictional losses in fluid flow upwardly through the conduit **32** result in a pressure gradient of 100 p.s.i., the choke should be chosen so as to achieve a pressure gradient thereacross of 2,400 p.s.i. The conduit **32** is also provided with a check valve **35** in order to provide for unidirectional flow from the first production interval to the second production interval. Thus, should the natural order of pressure relationships be reversed, the valve **35** will ensure that fluid will not flow from the upper production interval **19** to the lower production interval **28**. In some instances the valve **35** will be unnecessary. The choke and check valve are mounted in a removable tool **36** which is threaded to the conduit **32** as indicated by reference numeral **37**. It usually will be desirable to connect the tool **36** near or at the upper end of conduit **32** as shown in order to provide for simplicity of installation and withdrawal of this tool.

The elimination of tubing, a commingling tool or other like downhole well equipment from the blast-zone area opposite the perforations **18** greatly reduces the possibility of erosion of such equipment and makes unnecessary the provision of a blast-zone protector for such equipment. In addition, by the present invention, such erosion as takes place within the upper production interval will usually prove to be beneficial. In this regard, detrital material entrained in the fluid entering the well through perforations **18** may tend to cause additional perforations in the casing. For example, fluid flowing through the lowermost perforation **18** may be of a velocity such that entrained detrital material will tend to erode the opposite wall of the casing at the area generally designated by reference numeral **18***a*, ultimately causing a perforation at this location. The presence of such additional perforations will increase the cross-sectional area open to the flow of fluid from the formation with the attendant result that the entrained detrital material from the formation **12** will enter the well at a reduced velocity. This diminishes the brasive action of the entrained detrital material and may allow the subsequent location of downhole equipment within the blast-zone area, if this should become desirable. For example, after the formation of one or more additional perforations as described above, the abrasive action may be reduced such that a tubing string may be extended through interval **19** in the event it becomes desirable to produce formations **12** and **14** separately.

If the formation **12** is a gas reservoir, and if the perforations **18** are equally open to fluid flow, gas normally will enter through each of these at substantially the same velocity. However, in some cases, the fluid flowing through the lower perforations of the production interval **19** may be at a relatively low velocity as compared with fluid issuing through the perforations in the upper portion of the production interval **19**. This condition may exist, for example, where formation **12** is an oil and gas reservoir with gas production primarily through the upper perforations and oil production primarily through the lower perforations. As will be understood by those skilled in the art, the oil normally will enter through at a relatively low velocity with a resultant low erosion potential. Also, even though formation **12** is primarily a gas reservoir, the flow velocity through the lower perforations may be relatively low because of localized permeability dissimilarities in the formation adjacent the well. For example, the permeability of the formation **12**

adjacent the lower perforations may be low due to a tight rock structure or to localized damage to the formation as may occur during completion of the well.

In view of the above discussion, it will be recognized that the location of the upper end of conduit **32** may vary depending upon the local conditions. Usually it will be preferred to terminate the conduit **32** at a point below the bottom of the production interval **19** as shown. However, in some instances it will be possible to extend the conduit **32** partially into the upper production interval **19** without serious erosion problems. In any case, the conduit **32** should terminate below the top of the upper production interval **19**.

It usually will be desired to monitor either continuously or intermittently the production rate from the formation **14** and also the bottomhole pressure at the lower production interval **28**. While, as described hereinafter, such measurements can be taken through the use of suitable wireline tools, it sometimes may be desirable to make these measurements at frequent intervals and/or over extended periods of time. In such situations, it is preferred to maintain the necessary measuring tools in the well during normal operations. A preferred installation for accomplishing this objective is shown in FIGURE 1.

With further reference to FIGURE 1, the tubing **32** is provided with a flow measuring device **38** and a pressure measuring device **42**. The measuring devices **38** and **42** may be of conventional design and may be provided with suitable communication channels for telemetering the desired information to the surface. Alternatively, the devices **38** and **42** may include recording means which may be withdrawn from the well as desired. The pressure measuring device should be located below the flow-restricting means **34** as shown in order that it may be responsive to the downhole pressure at the lower production interval. It usually will be desirable to similarly locate the flow meter **38** although this latter device may under appropriate circumstances be located at any position within the flow path from the lower production interval to the upper production interval.

The total flow from the well may be measured at the wellhead by conventional practice. Thus, it can be seen that knowing the production rate of the lower formation **14**, the production rate from the upper formation **12** can be determined.

As noted previously, the bottomhole pressure at the upper production interval **19** should, during normal operation of the well, be maintained at some desired value less than the pressure of the formation **12**. An increase in the bottomhole pressure will result in a lower production rate from the formation **12**, and, of course, a bottomhole pressure in excess of the formation pressure will result in fluid flow from the well into the formation with possible deleterious effects. Such a pressure increase at interval **19** may be due to factors such as shutting in or throttling of the well at the wellhead or a rise in the production rate from the lower formation **14**.

With reference to FIGURE 2, there is shown a modified form of the invention in which the flow-restricting device is adjustable and responsive to pressure changes in the upper production interval **19**. Also, in the embodiment of FIGURE 2, the packing means separating the upper and lower production intervals and the conduit providing a flow path are formed as a single unit. The installation shown in FIGURE 2 is otherwise somewhat similar to that illustrated in FIGURE 1 and like elements in FIGURE 2 are designated by the same reference numerals as used in FIGURE 1.

In the embodiment of FIGURE 2, the well is cased adjacent the lower formation **14** by means of a liner **40**. The liner **40** is cemented in place and the liner and the surrounding cement sheath **42** are provided with a plurality of perforations **44**. The perforations **44** define a lower production interval **46** in the well, similar to the production interval **28** described above with reference to FIGURE 1. The packing means separating the upper and lower formations takes the form of an annular plate **48** which is formed integrally with the liner **42**. Extending through the packing element **48** is a conduit **50** similar in function to the conduit **32** in FIGURE 1. This liner, packing element, and conduit installation may be utilized in those instances where it is not desired to case the entire interval of the well between the upper and lower formations. This embodiment offers certain advantages in that the complete downhole installation including the liner, packing element and conduit may be run into place within the well as a single unit and in a single operation.

The conduit **50** is provided with a flow-restricting means which is responsive to pressure changes in the upper production interval **19**. More specifically, there is provided an adjustable flow-restricting device **54** and means responsive to an increase in pressure within the upper production interval **19** for decreasing the rate of flow of the lower formation fluid through the conduit **50**. The flow-restricting device **54** is connected in the tubing **50** by means of a threaded coupling **55**. Thus, the device **54** may be withdrawn or run into place by suitable wireline techniques. The device **54** comprises a valve member **56** which has an upper face **57** and which is slidably mounted within an outer case **58**. The valve member is biased away from a valve seat **59** by means of a compression spring **60** which is interposed between appropriate shoulders on the valve member and the case as shown. Upward movement of the valve member is limited by means of a stop element **61** on the outer case.

When the valve **56** is open as shown, fluid from the lower formation travels upwardly through the conduit **50**, through passages **62**, and thence through the throat **64** of the valve member. The compression in the spring **60** and the surface area of face **57** are balanced such that the valve remains in an open position under the desired back pressure within the upper production interval **19**. From an examination of FIGURE 2, it can be seen that an increase in pressure within interval **19** above the desired level will cause the valve member **56** to move downwardly, thus throttling further the fluid flow through the restricting means until it reaches a value consistent with the pressure desired in interval **19**. Of course, should this pressure then decrease, the valve member will open somewhat thus increasing the flow rate of the lower formation fluid as necessary.

It will be noted that the modification of FIGURE 2 does not include downhole devices for measuring flow rate or pressure. Such production measurements may be accomplished in this embodiment through the application of suitable wireline techniques. For example, a downhole flow meter such as that described in Godbey, J. K., "New Flowmeter Gives Water-Injection Profiles," "The Oil and Gas Journal, Mar. 12, 1962, pp. 92–95, may be lowered to a position below interval **19** and the flow rate from formation **14** measured. The flow rate of upper formation **12** then may be determined from total production rate measurements taken at the surface of the well. Alternatively, the production rates from formations **12** and **14** may be determined by measuring the flow from the well with both formations producing and also with formation **14** shut in. It will be recognized that downhole pressure measurements also may be taken through the use of suitable wireline tools.

As is known to those skilled in the art, the erosion of a surface by abrasive particles depends upon factors such as the velocity and quantity of the particles, and also their size, shape and hardness. Of these, the velocity of the particles as they strike the surface usually is the single most important factor. While erosion and ultimate failure of well tubing may occur at low velocities depending upon local conditions, experience has shown that in most wells, blast-zone erosion becomes significant at particle velocities of about 20 feet per second. While blast-zone

protectors such as those noted above afford a measure of protection, these oftentimes are readily susceptible to erosion at the higher particle velocities, particularly those on the order of 200 feet per second and above. Accordingly, while the invention may be utilized under any conditions in which the fluid from an upper formation has entrained therein sand or other detrital material, it is particularly useful where particle velocities are at least 20 feet per second, and especially so where particle velocities are at least 200 feet per second.

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 the recovery of fluids through a well penetrating at least two vertically spaced upper and lower subterranean formations, the pressure of said lower formation being greater than the pressure of said upper formation, said well being open to said lower formation through a lower production interval and to said upper formation through an upper production interval comprising a section of perforated casing, the method comprising:

producing fluid from said lower formation into said well through said lower production interval,

producing fluid from said upper formation into said well through said upper production interval whereby said fluid flows into the interior of said section of casing through perforations therein, said fluid having entrained therein abrasive detrital material,

flowing said lower formation fluid through a flow path within said well from said lower production interval to said upper production interval,

within said flow path, reducing the pressure of said lower formation fluid to a value less than the pressure of said upper formation,

commingling said lower formation fluid with said upper formation fluid by contacting said upper formation fluid as it flows into the interior of said section of casing through the perforations therein with said lower formation fluid, and

withdrawing said commingled fluids from said well.

2. The method of claim 1 wherein the pressure of said lower formation fluid is reduced within said flow path to a value which is lower than the pressure of said upper formation by at least the greater of 200 p.s.i. and 10% of the pressure of said upper formation.

3. The method of claim 1 wherein detrital material entrained in the fluid from said upper formation enters into the interior of said casing at a velocity of at least 20 feet per second.

4. The method of claim 1 wherein detrital material entrained in the fluid from said upper formation enters into the interior of said casing at a velocity of at least 200 feet per second.

5. The method of claim 1 wherein detrital material entrained in the fluid from said upper formation erodes at least one additional perforation in said section of casing and further comprising the step of, subsequent to the eroding of said additional perforation, locating downhole equipment within said upper production interval.

6. In a well penetrating at least two vertically spaced upper and lower formations, said well being open to said lower formation through a lower production interval and to said upper formation through an upper production interval comprising a section of perforated casing, the combination comprising:

packing means within said well separating said upper and lower production intervals,

a conduit extending through said packing means and terminating at a level below the top of said upper production interval and opening into the interior of said casing, said conduit providing a passageway for the flow of fluid recovered from said lower formation to said upper production interval within which said lower formation fluid is commingled with fluid recovered from said upper formation,

adjustable flow restricting means within said conduit for reducing the pressure of the lower formation fluid as it passes through said conduit, and

means responsive to an increase in pressure within said well above said packing means for adjusting said restricting means for decreased fluid flow through said conduit.

7. In a well penetrating at least two vertically spaced upper and lower formations, said well being open to said lower formation through a lower production interval and to said upper formation through an upper production interval comprising a section of perforated casing, the combination comprising:

packing means within said well separating said upper and lower production intervals,

a conduit extending through said packing means and terminating at a level below the top of said upper production interval and opening into the interior of said casing, said conduit providing a passageway for the flow of fluid recovered from said lower formation to said upper production interval within which said lower formation fluid is commingled with fluid recovered from said upper formation,

flow restricting means within said conduit for reducing the pressure of the lower formation fluid as it passes through said conduit, and

a check valve in said conduit allowing unidirectional flow from said lower production interval to said upper production interval.

8. In a well penetrating at least two vertically spaced upper and lower formations, said well being open to said lower formation through a lower production interval and to said upper formation through an upper production interval comprising a section of perforated casing, the combination comprising:

packing means within said well separating said upper and lower production intervals,

a conduit extending through said packing means and terminating at a level below the top of said upper production interval and opening into the interior of said casing, said conduit providing a passageway for the flow of fluid recovered from said lower formation to said upper production interval within which said lower formation fluid is commingled with fluid recovered from said upper formation,

flow restricting means within said conduit for reducing the pressure of the lower formation fluid as it passes through said conduit, and

pressure measuring means within said passageway and located below said flow restricting means.

9. The combination of claim 8 further comprising flow measuring means within said passageway.

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166—115, 133, 224

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,460,626 Dated August 12, 1969

Inventor(s) Henry L. Ehrlich

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 14, "multiple-completed" should read --multiply-completed--;
line 39, "multiple-completed" should read --multiply-completed--;
line 41, "multiple-completed" should read --multiply-completed--;
line 65, "multiple-completed" should read --multiply-completed--.
Column 2, line 34, "and" should read --of--.
Column 5, line 15, "include" should read --includes--;
line 67, "2000" should read --200--.
Column 6, line 48, "brasive" should read --abrasive.
Column 10, line 72, "JAN" should read --IAN--.

SIGNED AND
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APR 7 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents