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METHOD FOR PRODUCTION OF FLUIDS FROM A WELL

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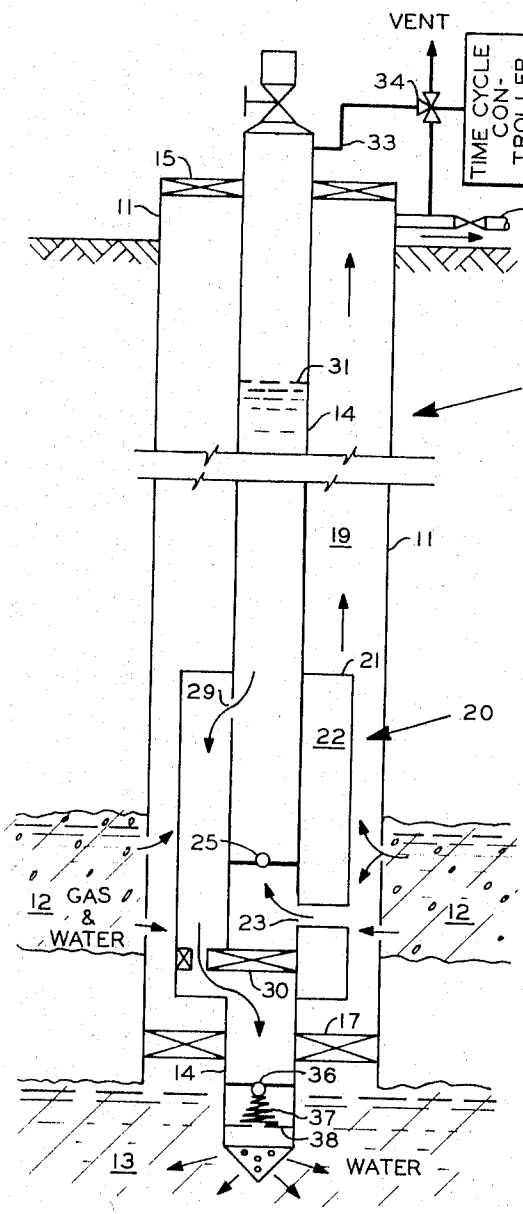

FIG. 1

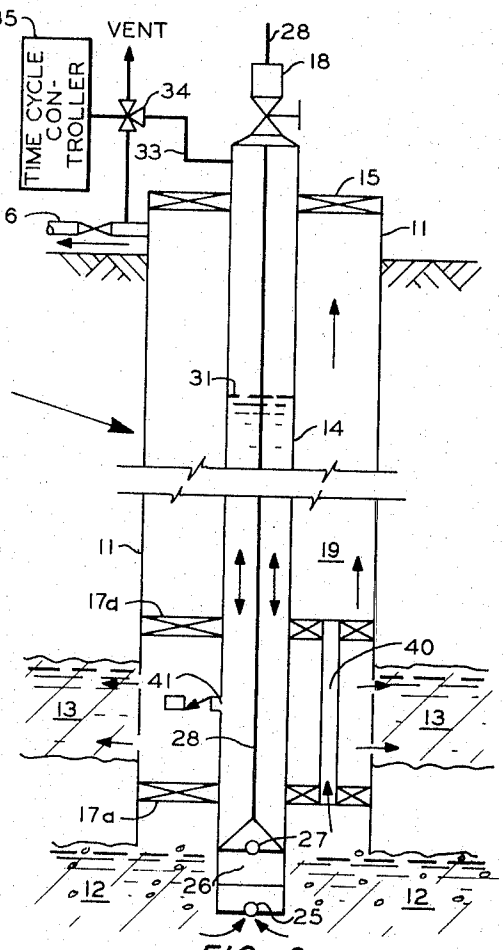

FIG. 2

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METHOD FOR PRODUCTION OF FLUIDS FROM A WELL

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This invention relates to the production of fluids from a well. In one of its aspects it relates to the production of gas where water is produced along with the gas. In still another of its aspects, the invention is concerned with the production of gas and water from a natural gas-and-water-bearing formation wherein the natural gas is produced at the surface and the water is disposed of or injected into a water-bearing formation in the same well bore. In another aspect the invention relates to apparatus for producing gas and water from a sub-surface formation wherein there is provided a tubing string, a well casing, a packer for sealing between the tubing and casing at a point between the said sub-surface formation and a water disposal formation, and a cross-over tool in said tubing string adapted to communicate with the said tubing string and with the annular space between said tubing and casing. In still another aspect, the invention relates to production of a mixture of fluids from a sub-surface formation wherein fluids other than water are produced to the surface by way of the annular space between the well casing and a well tubing and the water is disposed of in a separate but adjacent water-bearing formation utilizing the said tubing and a cross-over tool to conduct the water to said water-bearing formation, said formations being separated by a well packer. In yet another aspect, the invention relates to the production of gas from a gas and water-bearing formation wherein the gas and water flow into a well casing, the gas rises to the surface, the water enters a cross-over tool and rises inside a tubing string, and then under pressure sufficient to overcome the pressure of a disposal formation, the water passes through the cross-over tool, past a packer or seal and thence into a disposal formation. It is a further aspect of the invention as described above to utilize a disposal formation above or below the producing formation. In still a further aspect of the invention, gas pressure from the annular space is applied to the column of water in the tubing to force the same into the disposal formation.

In the production of natural gas from subsurface formations, it frequently occurs that some water is produced into the well bore along with the natural gas. When this occurs, the water must be removed from the bottom of the well bore if continued production of the gas is to be possible. If gas is produced under sufficient pressure and in sufficient volume, the water can be carried out of the well bore by the gas itself. In other instances, however, the water will accumulate at the bottom of the well bore and will ultimately build up to a height within the well bore sufficient to overcome the pressure of the gas in the formation and thus choke off the production of gas.

Numerous procedures have been followed in the past for the removal of water accumulating in the bottom of a gas well. One common expedient is to install an inner string of tubing and a conventional bottom hole pump. With this type installation the natural gas is allowed to rise through the annular space between the well casing and the tubing and is produced in normal fashion therefrom. The water is pumped up through the tubing to the surface of the earth and is disposed of from that point.

Water produced from deep formations within the earth frequently contains large amounts of natural salts. For this reason, the produced salt water cannot be disposed

of by allowing it to flow into surface streams. Instead, the preferred disposal, and, in fact, the required disposal, is to introduce the water into a subsurface formation where no damage can result. This requires that a disposal well be provided for disposing of the produced salt water. In those areas where producing gas wells are widely separated, the cost of drilling disposal wells for each producing well is prohibitive. In such instances, it is necessary to lay a costly pipeline gathering network to bring all of the produced water to a central location, or alternatively, to transport the produced water by trucks or similar vehicles. Regardless of the method used for transporting the salt water from the producing well to the disposal well, the cost of such disposal can be, and often is, prohibitive.

Many subsurface formations are both porous and permeable and such formations contain fluid of some sort. If the fluid is not oil or gas, it is water. In fact, most permeable formations contain some amount of water. Any water-bearing subsurface formation which contains salt water is suitable for the disposal of produced salt water. Fresh water formations, on the other hand, must be avoided because it is desirable to protect the fresh water formations for uses other than that associated with the production of oil or gas. It is very common for a porous and permeable salt water formation to lie closely adjacent to a producing gas formation. Such formation then can be used for a disposal of water produced with the natural gas.

Accordingly, it is an object of this invention to provide method and apparatus for the disposal of water produced with another fluid in a formation adjacent the producing formation. It is a further object of the invention to provide method and apparatus for disposing of this water using the same well bore as that used for the production of the fluids. It is a particular object to provide method and apparatus for producing gas and water from a subsurface formation wherein the gas is produced to the surface and the water is disposed of in a formation open to the same well bore.

According to the invention, a gas-and-water-producing formation and a separate but closely adjacent water-bearing formation are both opened to a well bore. The well bore is equipped with the usual casing and also with a tubing string. A mechanical seal such as a packer is placed between the gas-producing formation and the water-bearing formation. Gas is then produced from the producing formation into the annular space between the casing and tubing and thence upwardly to the surface where it is led off by a suitable pipe to a point of utility. The water is produced into the tubing string where it rises upwardly. When the water rises to a sufficient height to overcome the hydrostatic pressure of water in the water-bearing formation, it is allowed to pass downwardly through a by-pass to enter the water-bearing formation for disposal. In one embodiment of the invention, the water rises under pressure of the formation into the tubing to its maximum possible height. This is possible because the upper end of the tubing string is vented to the atmosphere. When the water has so risen into the tubing string a time cycle controller at the surface connects the annular space between the tubing and the casing to the interior of the tubing, thus making available the pressure of the gas in this annular space which pressure in turn is added to the hydrostatic head of the water which will be sufficient to force the water out into the water-bearing formation.

The invention will be more fully explained in the following specification, the claims and the drawing in which:

FIGURE 1 shows an embodiment of the invention where the gas-producing formation is above the water-bearing disposal formation;

FIGURE II shows an embodiment of the invention where the gas-producing zone is below the water disposal formation.

Referring to FIGURE I there is shown generally at **10** a well penetrating the earth to gas-producing formation **12** and a water-bearing formation **13**. The well bore is equipped with conventional casing **11**, which, according to customary practice, is cemented to the well bore to prevent migration of fluids from one zone to another. Gas-and-water-producing formation **12** communicates with the well bore as does water-bearing formation **13** by means of openings or perforations in casing **11**. Installed inside the casing is a string of tubing **14** which is sealed off with respect to the casing at the top by means of a seal **15**. In operation, gas produced from formation **12** rises through the annular space between casing **11** and tubing **14** and is drawn off by means of a valved production pipe **16** to further use. Tubing **14** is provided with a packer or other mechanical seal **17** to seal off the annular space between the gas-and-water-producing formation and the water-bearing formation. Installed in tubing string **14** is a by-pass or cross-over tool indicated generally at **20**. As shown in FIGURE I the cross-over tool **20** comprises a cylindrical member **21** which surrounds the tubing for a portion of its length and which cylindrical member is sealed at its top and at its bottom to tubing **14**. An annular space **22** is provided between the cylindrical member **21** and tubing **14**. Passageway **23** provides communication between annular space **19** and the interior of tubing **14**. Annular space **22** communicates with the interior of tubing **14** as indicated by passageway **29**. Below standing valve **25** and also below passageway **23**, tubing **14** is sealed off as at **30**.

Annular space **22** also communicates with the tubing **14** beneath the seal **30**. In operation then, gas and water are produced from formation **12** into annulus **19** where the gas rises through the annulus to be produced by way of pipe **16**. Water enters tubing **14** by way of passageway **23** and rises inside the tubing. After the water has risen to a height sufficient to overcome the pressure inside formation **12**, it will cease to rise further. When this occurs, no more water can enter the tubing but water will rise inside annulus **19** and this will tend to cut down or reduce flow of gas from formation **12**. To operate the well, it is necessary that any gas above the column of water in the tubing be vented to the atmosphere. This is conveniently done by way of pipe **33** and three-way valve **34** which in one position vents the pipe **33** to the atmosphere.

The characteristics of the particular well will determine the length of time it takes for water to rise to any desired height within the tubing. Accordingly, a time cycle controller **35** can be set to switch the position of valve **34** so that pipe **33** communicates with pipe **16**. Since pipe **16** will have a pressure within it representative of the pressure against which the well is delivering gas, this pressure now becomes available to force the column of fluid inside pipe **14** back downward into water-bearing formation **13**. Standing valve **25** prevents the forcing of water from tubing **14** back into formation **12**. After sufficient time has elapsed, time cycle controller **35** will switch valve **34** so that it again vents to the atmosphere.

A valve **36** is installed near the lower end of tubing **14** to prevent upward flow of water from formation **13** in case the pressure of that formation is greater than the pressure inside tubing **14**. The ball of valve **36** is biased upwardly by spring **37** which is supported by a stop **38**.

The embodiment of the invention depicted in FIGURE II is very similar to that of FIGURE I excepting that water-bearing formation **13** is above gas-and-water-producing formation **12**. In FIGURE II the apparatus is given numerals like those of FIGURE I wherever such apparatus is identical. The principal differences are that two packers **17***a* are used instead of one, and that a bottom hole pump can be used. The packers **17***a* are set above and below the water-bearing formation. Gas

entering the well bore from gas-producing formation **12** rises through annular space **19** to the lower packer and thence by way of communicating tube **40** to the space above the upper packer from whence it travels to the surface and is produced through pipe **16** as before. Water enters pipe **14** by way of standing valve **25** and either rises above the level of formation **13** due to its own pressure, or is pumped up by a conventional bottom hole pump. The pump is schematically represented by plunger **26** and travelling valve **27**. The plunger **26** is actuated by rod string **28** which extends to the surface and which in turn is reciprocated by a conventional beam pumping unit. Tubing **14** is provided with a conventional lubricated stuffing box assembly **18** to seal between the rod string **28** and tubing **14**. The beam pumping unit forms no part of this invention and is not illustrated. After it has reached a suitable height **31** in the tubing, the water travels out through passageway **41** into water-bearing formation **13**. The apparatus of FIGURE II can be operated without the bottom hole pump in the same fashion as FIGURE I. Time cycle controller **35**, three-way valve **34**, and pipe **33** operate in the same fashion as described previously.

The operation of this invention may be illustrated by assuming that the pressure of the gas and water entering the well bore is 300 pounds per square inch and the pressure of the water bearing formation is 450 pounds per square inch. Gas is flowing from the top of the well at a pressure of 250 p.s.i. With the upper end of tubing **14** vented to a low pressure zone or to the atmosphere via pipe **33** and three-way valve **34**, water then enters tubing **14** via passageway **23** and rises upwardly until the hydrostatic head of water inside the tubing approaches the flowing bottom hole pressure of 300 p.s.i. At this time, time cycle controller switches valve **34** so that the interior of tubing **14** communicates with pipe **16** via pipe **33** and valve **34**. When this is done, the 250 p.s.i. gas pressure in pipe **16** is imposed on the top of the water in tubing **14** so that this pressure is added to the hydrostatic pressure of the water to give a total pressure at the bottom of tubing **14** of 550 p.s.i. This is greater than the pressure in formation **13** and the water will be forced downwardly and out into the formation. As the water is forced down, the hydrostatic pressure will become less so that after a time, the pressure within tubing **14** is approximately equal to the pressure in formation **13** and disposal of water thereinto will cease. At this time, time cycle controller will switch back to the vent position to allow additional water to enter the tubing. Standing valve **25** prevents water from returning to the producing formation, and valve **36** prevents water from formation **13** from entering the tubing.

Desirably, water-bearing formation **13** is separated from producing formation **12** by an impermeable zone. This impermeable zone can be only a few feet in thickness or it may be much more.

It is generally unnecessary to use a bottom hole pump unless formation **13** is substantially below formation **12**. It is understood, of course, that while a simple type of pump has been illustrated in the drawing, other well-known pumps can be used. For example, the pump can be of the traveling barrel or of the traveling plunger type. In the first of these, the outer barrel of the pump reciprocates with respect to the plunger which is stationary. As to the traveling plunger type pumps, the plunger moves with respect to a stationary barrel. In either instance, the traveling valve is usually associated with the moving part and the standing valve with the stationary part.

It will also be apparent that the method and apparatus herein described can be used where the fluids produced from the subsurface formation comprise water and oil or water, oil and gas.

Reasonable variation of the invention as set forth in the drawing, specification and claims will be apparent to one skilled in the art, the essence of the invention

being that there is provided method and apparatus for producing gas from a fluid-and-water-bearing formation, wherein the fluid is produced to the surface and the water is raised a sufficient height inside a tubing string to permit injection and disposal of the water into an adjacent water-bearing formation.

I claim:

1. A method for the disposal of water produced along with gas in a gas well having a tubing string and a well casing therein comprising the steps of:
   (a) sealing off a portion of the well bore between a lower gas-and-water-producing formation and an upper water-bearing formation with sealing means;
   (b) producing gas from said gas-and-water-producing formation by way of an annular space between the said well bore and an inner tubing string and upwardly through a passageway in said sealing means;
   (c) mechanically pumping water from said gas-and-water-producing formation upwardly in said tubing to a point such that the hydrostatic pressure created inside said tubing is greater than the hydrostatic pressure of water in said water-bearing formation;
   (d) and, in a cross-over zone, passing water from said tubing to said water-bearing formation whereby said water flows into said water-bearing formation.

2. A method for the disposal of water produced along with gas in a gas well having a tubing string and a well casing therein comprising the steps of:
   (a) sealing off a portion of the well bore between a gas-and-water-producing formation and a water-bearing formation;
   (b) producing gas from said gas-and-water-producing formation by way of an annular space between the said well bore and an inner tubing string;
   (c) venting to the atmosphere the upper end of said tubing string;
   (d) producing water from said gas-and-water-producing formation into said tubing string whereby said water rises in said tubing string to a point such that the hydrostatic pressure created inside said tubing is substantially equal to the flowing bottom hole pressure of said gas-and-water-bearing formation;
   (e) closing off the upper end of said tubing string and communicating the same with the said annular space whereby gas pressure available in said annular space is exerted on the top of the water inside said tubing; and
   (f) utilizing the combined pressures of the hydrostatic pressure of the said water inside the said tubing string and the gas pressure communicated from the said annular space, in a cross-over zone, passing water from said tubing downwardly to said water-bearing formation whereby said water flows into said water-bearing formation and is disposed therein.

3. The method of claim 2 wherein the said gas-and-water-producing formation is above the said water-bearing formation.

4. The method according to claim 2 wherein the said gas-and-water-producing formation lies below the said water-bearing formation.

5. The method of claim 2 further comprising the step of venting the upper end of the said tubing string after the water has been disposed of in said water-bearing formation.

6. The method of claim 5 wherein the steps of closing and venting are conducted in a regular timed sequence.

7. A method for the disposal of water produced along with another fluid in a water-and-other-fluid-producing well having a tubing string and a well casing therein comprising the steps of:
   (a) sealing off a portion of the well bore between lower a producing formation and an upper water-bearing formation;
   (b) producing said other fluid from said producing formation by way of an annular space between the said well bore and an inner tubing string;
   (c) producing water from said water-and-other-fluid-producing formation upwardly in said tubing to a point such that the hydrostatic pressure created inside said tubing is greater than the hydrostatic pressure of water in said water-bearing formation; and
   (d) in a cross-over zone passing water from said tubing downwardly to said water-bearing formation whereby said water flows into said water-bearing formation.

8. A method for the disposal of water produced along with gas in a gas well having a well casing and a tubing string therein, comprising:
   (a) producing gas under pressure in the annulus between said tubing string and said casing;
   (b) producing a column of water in said tubing string equal in height to the hydrostatic pressure of the producing formation;
   (c) communicating said annulus with said tubing string at a point above said column of water; and
   (d) forcing said water into a disposal formation under the combined pressure of said column of water and said gas.

9. The method of claim 8 wherein said producing formation is above said disposal formation.

10. The method of claim 8 wherein said producing formation is below said disposal formation.

11. A method for the disposal of water produced from a lower gas and water producing formation into an upper disposal formation comprising mechanically pumping said water upward in a well tubing to form a column of water of sufficient height above the level of said disposal formation to create a hydrostatic pressure at said level greater than the hydrostatic pressure of said disposal formation, and allowing said water to flow into said disposal formation.

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