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OPERATION OF GAS WELLS

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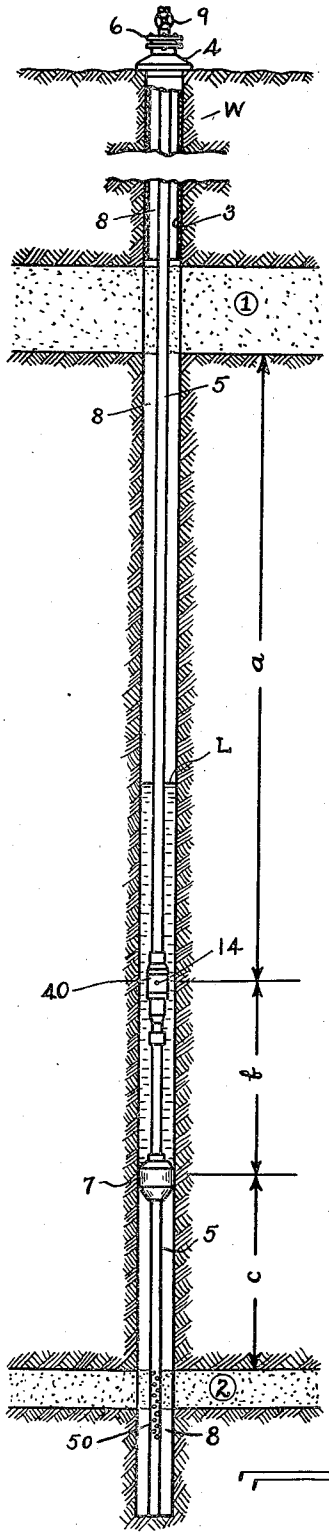


Fig. I.

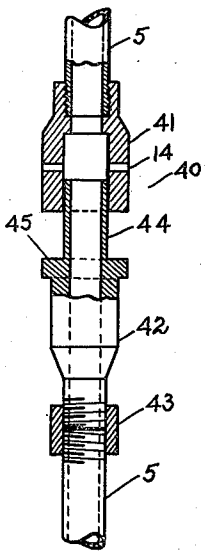


Fig. II.

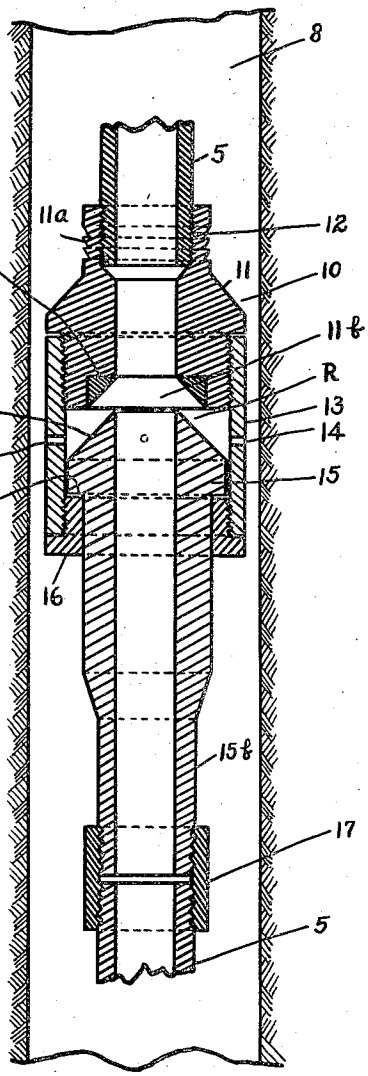


Fig. III.

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OPERATION OF GAS WELLS

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Application April 7, 1936, Serial No. 73,052

1 Claim. (Cl. 166—21)

My invention relates to natural gas-wells, and consists in an improved method of operating such wells. This application is a continuation in part of application Serial No. 756,773, filed by me on or about the 10th day of December, 1934.

The usual practice in gas-fields is to drill from the earth's surface downward to the first gas-yielding sand. A tubular casing is then installed in the subterranean bore, and connection is made at the earth's surface to a tank or pipe line for removal of the gas paid by the sand into such casing.

When in the operation of the well, the yield of this first sand becomes low, the bore is drilled deeper—down to the next lower or second gas-sand. Within the casing already installed a line of tubing is run down to this second sand, and the yield of the well then comprises the gas delivered by the second sand into the tubing, plus the yield of the first sand into the region between the tubing and the casing. When the yield of the second sand becomes low, the well is drilled to the third gas-sand, and the line of inner tubing is lowered into communication therewith. The gas yielded by the third sand is conducted through the inner tubing to the top of the well, and the gas yielded by both the first sand and the second is conducted upward in the region between the tubing and the casing. In such manner a gas-well is progressively drilled from one gas-yielding stratum to another, and two or more strata are held in communication with the outlet of the well.

Years ago, when the natural gas fields were first opened, it was found that gas-sands were naturally dry, or included oil in such small quantities as to be unobjectionable. While gas is usually present in oil-bearing sands, it is to be understood that there is a clear distinction in the art between a gas-sand and an oil-sand. A gas-well, properly considered, operates on gas-bearing strata and an oil-well operates primarily on oil-bearing strata. With these general distinctions in mind, it will be understood that my invention relates to the operation of gas-wells.

As above mentioned, with the gas fields of the country were first opened, the gas-sands were found to be substantially free of water, this being particularly true in the case of the eastern fields of the United States. And no great difficulty was experienced in operating gas-wells in the manner described. Today, however, conditions are different.

Due to carelessness, ignorance, and laxity of law, operators did not plug exhausted and abandoned wells, and over a period of years water from the earth's surface and from subterranean water sands and other water-bearing strata has been allowed to drain into such wells, with the consequence and effect that now most gas-sands in the eastern fields carry water.

Before considering the invention in detail, I shall describe a known method of operating a gas-well in which only the first and second gas-sands have been tapped. The water in the gas-yielding strata seeps into the bore of the well, and in relatively short time floods the bottom of the well to a level above the second sand, thereby throttling the yield of such sand. When this occurs the normal operation of the well is intermitted, and the water is removed in known way by means of a bailer, lowered through the inner line of tubing. The bailing operation is slow, and during the operation substantial quantities of gas are lost at the mouth of the well. When the water has been bailed out, the well is restored to normal operation.

The seepage of water from the gas-sands and other water-bearing strata continues and soon floods the second sand again. The bailing operation must be and is repeated, and in many cases the expense and losses occasioned by the frequent bailing operations turn economic success to failure. For this reason many fields in which gas still exists have been abandoned.

I am aware of another known method which has been proposed for removing liquid from wells, but so far as I know it has never proved adequate in solving the problem of seepage in gas-wells. Such method consists in cementing the lower end of a line of tubing in communication with the lower gas-sand, in such manner that the water seeping from the upper sand is collected in the bore of the well above the body of cement and externally of the line of tubing. Thus, only the relatively slight seepage from the lower stratum drains to the bottom of the well, whereby the intervals between floodings and the periods between bailing operations are greatly increased. The relatively large seepage from the upper sand (and from other water-yielding strata above) collects in the well above the body of cement at the base of the tubing and sooner or later rises to such level that the upper sand is flooded. In order to remove such water, a ported coupling is included in the inner line of tubing, opposite to or at the base of said upper sand, and from time to time the ports of the coupling are opened, permitting the water collecting in the well above or opposite to the upper sand to drain into the inner tubing, whence

it may be bailed out, or blown to the top of the well by the gas streaming at high velocity upward through the tubing from the lower gas-yielding sand. It is characteristic of this proposed practice that the upper sand is never completely drained; it is normally flooded to greater or less degree, and the gas yielded by the sand must bubble through the liquid and rise. Of course, in new fields in which gas is delivered under high pressure, an adequate yield sometimes may be obtained from a flooded or partially flooded gas-sand, but in a well in which the upper sand yields gas under relatively low pressure this method is unsuitable. And even in high pressure wells the flooding of the yielding sands holds the delivery far below what it might otherwise be. If the lower portion of a sand stratum is inundated, even if only for a relatively short time, it will be readily understood that water, due to capillary attraction, will be drawn up into the body of sand above the water, and will operate to constrict the gas-delivering ways and passages between the grains of sand. In accordance with my invention I provide a method of operating a gas-well, whereby the entire upper gas-yielding stratum (or strata) is maintained substantially dry. Thus I obtain maximum yield in any gas-well having two or more paying sands in operation, and in particular I make it feasible to operate gas-wells in fields which hitherto have been abandoned.

In the accompanying drawing, Fig. I is a diagrammatic, sectional view of a gas-well prepared for operation in accordance with the invention; Fig. II is a view in section and to larger scale of a particular coupling employed in the well; and Fig. III is a sectional view to still larger scale of a coupling of modified and preferred form.

In exemplary way a gas-well W is shown. It is shown to be drilled to the second gas-sand **2**, and an outer casing **3** is installed in the well above the first gas-sand **1**. A line of tubing **5** is run downward through the casing **3** and bore **8** of the well and terminates in a perforate footer **50**, through which gas yielded by the sand **2** enters the bottom of the tubing and streams upward to the top of the well. The gas delivered by sand **1** flows upward between the tubing **5** and casing **3**. The tubing **5** provides an inner passage, and the region between such tubing and the wall of bore **8** (and casing **3**) provides an outer passage for conducting gas from the two strata **1** and **2** to the top of the well. A header **4** of usual sort is provided at the mouth of the well, and a pipe connection, subject to a valve **9**, is made to a convenient receiver or pipe line (not shown).

The vertical interval between the two gas-yielding strata **1** and **2** will be found to vary in different fields, and in this case two hundred and fifty feet is given as exemplary. In the course of operation of the well water seeps from the sands **1** and **2** (and usually from other subterranean strata through which the well extends) into the bore of the well, and, as has been above indicated, my invention consists in a procedure whereby the normal tendency of such water to reduce the yield of the well is eliminated or effectively minimized.

I install in the well a removable packer **7**, a well-known device serving in known way to plug the outer passage of the well while leaving the passage within tubing **5** unconstricted. Removability of the packer is desirable, to the extent that it permits the withdrawal of the tubing **5** and the drilling of the well to lower depths, when the yield of the sands **1** and **2** falls off. In accordance with the invention, the packer **7** is installed and interval *c* above the sand **2**, and an interval *a*+*b* below the sand **1**. A ported coupling **40**, having its ports **14** normally closed, is installed in the line of tubing **5** an interval *b* above the packer. During the normal operation of the well, the water seeping in relatively small quantities from the sand **2** is collected in the bottom of the well, and ordinarily the pool of water rising in the bottom of the well will require from one to three weeks to reach such level as to throttle the yield of the sand **2**. When such yield does become so throttled, a bailer is lowered through the tubing **5** and the collected water removed in the usual way. The water seeping in relatively large quantities from the upper sand **1** (and from other water-bearing strata) drains into the bore of the well beneath the sand **1** and above the packer **7**, while the gas yielded freely flows upward between tubing **5** and casing **3**. It will be perceived, therefore, that the bore of the well above the packer **7** and beneath sand **1** comprises a reservoir for the seepage water, and that the effective depth of such reservoir is the interval between the ports **14** of the coupling and the bottom of upper sand **1**.

The seepage reservoir has a relatively great volumetric capacity. In the given case the interval *a* equals 150 feet, *b* equals 50 feet, and the bore **8** of the well is eight inches in diameter. Accordingly, the reservoir is of over 50 cubic feet effective capacity. Starting with the reservoir empty, the well may be operated from one to four or more weeks (depending on the rate of seepage) before the pool rising in the reservoir reaches the bottom of the sand **1**. When the water reaches the sand **1**, or before it does so, the normal operation of the well is interrupted, and, in a manner presently to be described, the ports **14** lying relatively close to the bottom of the reservoir are opened, and the collected water is drained into the tubing **5**, whence it may collect at the bottom of the well and be removed by bailing, or, to greater advantage, may be blown out of the well in the manner already alluded to. In either case the water is readily removed from the reservoir, and the well restored to normal operation. It will be perceived that by virtue of this method I can operate the well over relatively long intervals of time, without the sand **1** becoming flooded. Indeed, the sand **1** may be maintained in a drained, substantially dry condition. It will be noted that the ports **14** are located an interval *b* above the packer. This interval (50 feet in this case) provides at the bottom of the reservoir adequate space for the accumulation of sediment and dirt, which might otherwise plug the orifices **14**.

It appears that the practice of my invention in one well of a field proves beneficial to adjacent wells. That is to say, I have found that the practice of my invention in one well operates to bring to life sands which were considered dead and non-yielding in adjacent wells.

While many various provisions may be made for draining the water from the bottom of the reservoir into the tubing **5**, an expansible coupling is particularly desirable. Turning to Fig. II, the expansible coupling **40** is shown in detail. It will be seen that the tubing **5** is parted at the coupling, the coupling consisting of a cylinder portion **41** secured to the lower end of the upper section of tubing **5**, and a tubular portion **42** secured by a union **43** to the upper end of the lower section of tubing **5**. The portion **42** in-

cludes a hollow plunger 44 extending upward from a shoulder 45 and into the cylinder portion 41. In normal operation of the well, the lower edge of the cylinder portion 41 is seated upon the shoulder 45, and the tubular portion 44 extends upward into the cylinder portion and closes the ports 14 from within. When it is desired to drain the water from the reservoir into the tubing 5, the usual flanged connection 6 of the tubing 5 with the header 4 is released, and the upper section of tubing is elevated, so that the cylinder portion 41 is raised to the position shown in Fig. II. Thus, the ports 14 are opened, and the water collected in the reservoir drains into the tubing 5.

An expansible coupling 10 of modified and highly specialized structure is shown in Fig. III. Such coupling includes a head 11 which is secured in threaded union 12 to the lower end of the upper portion of the tubing that reaches from the coupling to the mouth of the well. The external wall of the head 11 is provided with circumferential serrations or "slip" rings 11*a*, whereby the coupling may be grappled with fishing tools in case it be "lost" in the well. The head 11 carries a cylinder portion 13 which includes a circumferentially extending line of relatively small orifices 14, and, within the cylinder portion 13, a plunger 15 is organized. The plunger is formed with an annular shoulder 15*a*, and a keeper 16 secured in the lower end of the cylinder portion 13 serves, in cooperation with such shoulder, to secure the parts in assembly; from within the cylinder portion 13, the plunger continues downward in a tubular extension 15*b* which is connected, by a union 17, to the upper end of the lower portion of tubing 5 that extends from union 17 to the bottom of the well. As the drawing indicates, the head 11 and plunger 15 are hollow, providing in conjunction with the tubing 5 a continuous passage from the bottom of the well to the top—a passage which normally is sealed from and independent of the outer passage (8) within which it extends.

Within the cylinder portion 13, the head 11 of the coupling is provided with an upwardly and inwardly tapering seat 11*b*, and, advantageously, the seat is provided in an inset block 11*c*. The plunger 15 is formed of a relatively non-corrosion metal, such as brass or bronze, and the block 11*c* is formed of a cuprous, nickel alloy, such as is commonly known as Monel metal. Otherwise, the coupling may be formed of cast iron or steel. The upper or inner end of the plunger 15 is conical, providing a tapered face 15*c* adapted normally to engage the seat 11*b*, and, when such normal condition prevails, the body of the plunger closes the orifices 14 from within. In the alternate or unseated position of the plunger, the ports 14 are uncovered.

In normal operation the lower end of the tubing 5 rests upon the bottom of the well, and, subject to the weight of the tubing 5 above, the head 11 of the coupling bears in seated position upon the upper, tapered end of the plunger 15. And if gas pressure exceeds the weight of tubing, the usual procedure is followed of using anchor rods and clamps.

When the reservoir is to be drained, the outlet of the tubing 5 is vented to the atmosphere, or into a low pressure receiver, and gas is permitted to stream violently upward through the tubing from the second sand 2. Then the upper section of tubing 5 is elevated, whereby the seat 11*b* is moved away from the face 15*c* of the plunger and the ports 14 opened, as shown in Fig. III. It will be observed that a region R is thus provided between the seat 11*b* and face 15*c*. This region R comprises a passage which is inclined upward, toward the course of gaseous flow within the tubing 5, whereby the gas streaming upward through the coupling produces a substantial aspirating effect. The orifices 14 are relatively small, so that water draining from the reservoir squirts in relatively fine streams into the region R. Due to the relatively small orifices and the aspirating effect, the liquid spurting into the coupling is broken up into small globules which are readily entrained with and carried upward by the flowing gas. Upon reaching the top of the well the entrained water is discharged into the atmosphere or the low pressure receiver, as mentioned. In such manner the water is progressively drained from the reservoir and removed from the well.

It has been found that the inwardly spurting liquid, in washing over the tapered surface 15*c* of the plunger and the tapered surface 11*b* of the block 11*c*, serves to cleanse the surfaces of such dirt and grit as normally tend to collect thereon, whereby, when the upper section of tubing is again lowered, to close the orifices 14, a snug engagement of the surfaces (11*b*, 15*c*) is insured.

I have found in a practical installation that, when the outer casing 3 comprises six inch pipe and the inner tubing 5 comprises two inch pipe, the orifices 14 may be four in number, and each may be $\frac{3}{16}$ of an inch in diameter.

What I claim as my invention is:

In the operation of a gas-well which includes an outer passage extending downward into communication with a subterranean gas-yielding stratum, and an inner passage extending downward into communication with a lower gas-yielding stratum, the herein described method which includes normally drawing off gas from said lower stratum and conducting it upward through said inner passage, drawing off gas and water from said upper stratum and causing such gas to flow upward and said water to drain downward in said outer passage, to a level below the upper stratum, collecting such water in a reservoir extending downward in said well a relatively great distance below said upper stratum and separated from said lower stratum, occasionally interrupting such normal operation, and, by establishing flow between said reservoir and said inner passage at a point substantially below said upper stratum, emptying said reservoir, removing from the well the water emptied from said reservoir, and thereafter restoring the well to normal operation, whereby said upper stratum is maintained in substantially dry condition.

GEORGE E. VAN VOORHIS.