

May 16, 1961

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2,984,303

SUBSURFACE APPARATUS FOR CONTROLLING WELL PRODUCTION

Filed Sept. 30, 1957

Fig. 1.

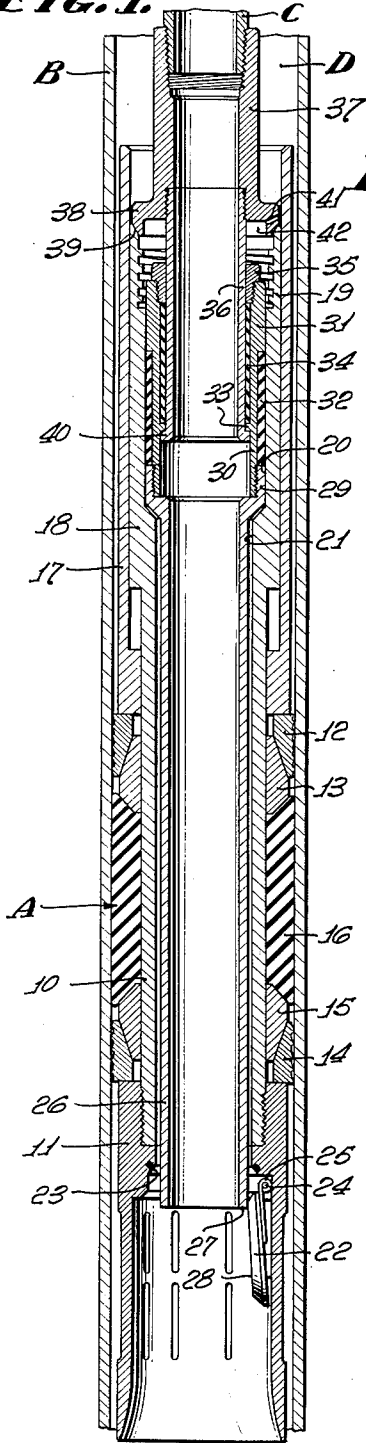


Fig. 2.

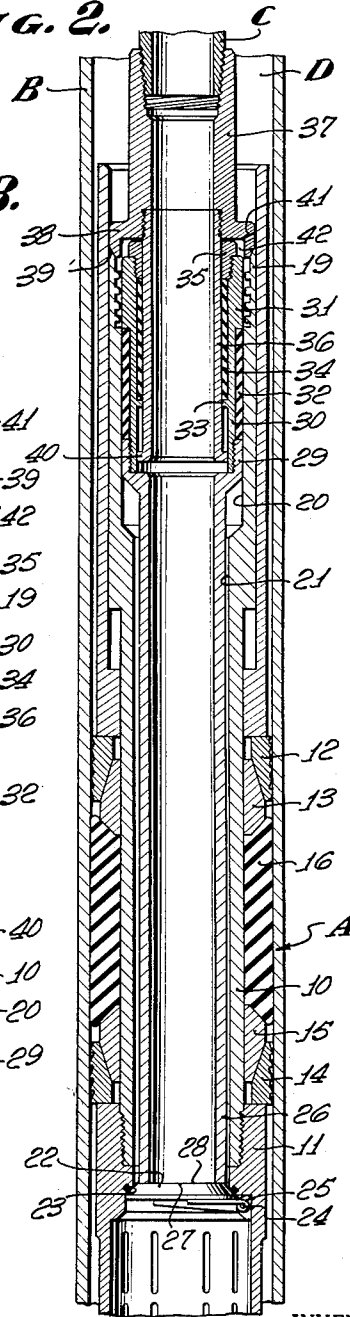
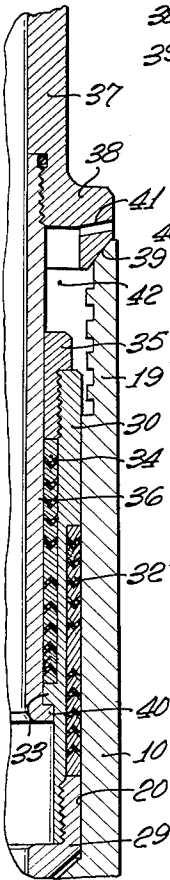


Fig. 3.



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SUBSURFACE APPARATUS FOR CONTROLLING WELL PRODUCTION

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Filed Sept. 30, 1957, Ser. No. 687,020

7 Claims. (Cl. 166—114)

The present invention relates to subsurface well apparatus, and more particularly to apparatus for controlling production from oil and gas wells.

An object of the invention is to provide improved apparatus for use in a well bore, which is capable of automatically shutting off the flow of well bore fluid in the event of damage to the well bore or the connections at the top of the well bore.

Another object of the invention is to provide apparatus for controlling flow of well fluid through a production tubing in which the apparatus will shut off such production in response to decrease of the pressure in the annulus around the production tubing to a predetermined value.

A further object of the invention is to provide production tubing apparatus to be used in conjunction with a well packer set in the well casing, the apparatus being capable of shutting off the flow of well production through the tubing at the location of the packer, such apparatus having an opening therethrough at least equaling the inside diameter of the tubing string.

Yet another object of the invention is to provide production tubing apparatus to be used in conjunction with a well packer that may have been installed previously in the well casing, the apparatus being capable of shutting off the well flow in response to the pressure in the annulus around the tubing dropping below a predetermined value.

An additional object of the invention is to provide subsurface production tubing apparatus for automatically shutting off the well production, which is comparatively simple, and easy and economical to manufacture.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of a form in which it may be embodied. This form is shown in the drawings accompanying and forming part of the present specification. It will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

Figure 1 is a longitudinal section through an apparatus disposed in a well casing, with the valve portion in open position;

Fig. 2 is a view similar to Fig. 1, with the valve portion shifted to a closed position;

Fig. 3 is an enlarged longitudinal section of a portion of the apparatus shown in Fig. 1.

The apparatus is particularly designed for use in connection with a well packer A that may have been previously installed in a well casing B. The well packer is adapted to control the flow of fluid from a production zone in the well bore below the well packer, the fluid flowing upwardly through the well packer and through a production tubing string C extending to the top of the hole. The pressure of the well production tends to maintain the apparatus in an open condition, so that the production can flow through the tubing string to the top of the hole.

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However, should the pressure in the annulus D between the tubing string and the casing decrease below a certain value with respect to the pressure of the well production, the valve portion of the apparatus will automatically close, to shut off the well production.

As illustrated in the drawings, the well packer may be of any suitable type consisting of a central tubular body 10 having a lower guide and junk pusher 11 attached thereto. A set of upper segmental slips 12 is anchored to the well casing by an upper expander 13 surrounding the body, to prevent upward movement of the body of the well packer in the well casing, whereas a set of lower segmental slips 14 is anchored by a lower expander 15, surrounding the body, to the well casing B to prevent downward movement of the body 10 in the well casing. A rubber or rubber-like packing sleeve 16 surrounds the body and has been compressed between the upper and lower expanders 13, 15 and expanded outwardly to firm sealing engagement with the wall of the well casing B, as well as with the periphery of the body 10. As shown in the drawings, a sleeve 17 may surround an enlarged head portion 18 of the body to bear against the upper slips 12, for the purpose of setting the latter.

Specific details of the well packer A form no part of the present invention. They may be found in the patent to Thomas M. Ragan, Patent No. 2,624,412. It is sufficient at this point to note that the upper end 19 of the packer body is flared in an outward direction to form a guide surface, that the upper portion of the packer body has a counterbore 20 of an internal diameter substantially greater than the internal diameter of the main portion of the body passage 21, and that the internal diameter of the body passage itself is substantially greater than the internal diameter through the tubing string C which is to be associated with the well packer, and which extends to the top of the well bore.

It is further to be noted that upward flow of fluid through the passage 21 may be prevented by the seating of a flapper valve head 22 against a companion valve seat 23 provided in the guide and junk pusher 11 of the body 10. This flapper valve head 22 is pivotally mounted on a hinge pin 24 suitably secured to the guide 11, there being a spring 25 surrounding the hinge pin and bearing against the valve head 22, tending to urge it in an upward direction into sealing engagement against the valve seat 23.

The well packer A is anchored in packed-off condition in the well casing above the zone in the well bore from which the well production is derived. This well production will flow into the casing string B and then upwardly through the well packer A and through the tubing C to the top of the hole, so long as the flapper valve head 22 is maintained in an open position. In the present instance, the valve head may be maintained in the open position disclosed in Fig. 1 by a tubular extension 26 disposed within the body of the well packer and which depends from the tubing string C itself. Specifically, the tubing extension can extend downwardly so that its lower end 27 engages the face 28 of the flapper valve head and holds it in a downward direction against the force of the spring 25 and in an open position. This tubing extension 26 has an upper enlarged head 29 adapted to slide along the inner wall of the body counterbore 20, this head being internally threaded for threaded attachment to the lower end of a piston sleeve 30 which extends upwardly therefrom and terminates in an upper piston portion 31. Disposed between the upper portion of the piston 31 and the upper end of the tubing extension 26 is an external or outer seal 32 adapted to slidably and sealingly engage the wall of the counterbore 20.

The piston structure also has an inwardly directed flange 33 at its lower portion engaged by the lower end of

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an inner seal structure 34 which is held in position on the piston 30, 31 by an upper piston nut 35 threaded into the upper portion of the piston. The inner flange 33, nut 35 and intervening seal structure 34 are slidable along the exterior or periphery of an inner sleeve 36, the upper end of which is threadedly secured to the lower end of a locator sub 37, which is, in turn, threadedly attached to the lower end of the tubing string C. The locator sub 37 includes a lower outwardly directed flange or head 38 having a lowered tapered surface 39 adapted to engage the upper end 19 of the packer body 10.

The tubing extension 26 and the piston structure 31 to 35, including the seals 32, 34, are slidable longitudinally within the packer body 10. Upward movement of the tubing extension and piston structure along the packer body 10 and the inner sleeve 36 is limited by engagement of the nut 35 with the lower portion of the locator sub 37. When in this upper position, the lower end 27 of the tubing extension is disposed above the valve seat 23, and the flapper valve 22 can then swing upwardly into sealing engagement with its companion valve seat. When the locator sub 37 is engaging the upper end 19 of the body, downward movement of the piston structure 31 to 35 and the tubing extension 26 within the packer body 10 is limited by engagement of the inner flange 33 with an external flange 40 at the lower end of the inner sleeve 36. When in this position, the lower end 27 of the tubing extension 26 is disposed across the face 28 of the flapper valve head 22 to hold it in the depending position disclosed in Fig. 1, which is a fully open position.

The internal diameter of the tubing extension 26, the inner sleeve 36 and the locator sub 37 are preferably no less than the internal diameter through the tubing C attached to the lower end of the locator sub and extending to the top of the well bore. Such arrangement is preferred, to provide no restrictions through the apparatus to the flow of fluids therethrough when the flapper valve head 22 is in the open position, or to the passage of other apparatus through the tubing string C and the well packer A.

Assuming that the well packer A has been previously anchored in packed-off condition in the well casing, the flapper valve 22 will be disposed upwardly against the valve seat 23 to prevent the well production from flowing upwardly through the body passage 21. That is, the lower production zone is shut in. When the production is to be conducted through the tubing string C to the top of the well bore, the tubing extension 26 and piston structure 31 to 35 is appropriately mounted on the inner sleeve 36, which is then threadedly attached to the locator sub 37. The latter is secured to the lower end of the tubing string C and this combination is lowered through the well casing B. The tubing string extension will enter the packer body 10 and will move downwardly thereinto until the locator sub 37 engages the upper end 19 of the packer body 10. At this time, the tubing extension 26 extends downwardly, with its lower end 27 adjacent the closed flapper valve head 22, whereas the inner and outer seal structures 32, 34 and piston 30, 31 may be disposed in an upper position within the counterbore 20, such as disclosed in Fig. 2. The flapper valve head 22 is still closed against its seat 23. The well production below the flapper valve head is acting in an upward direction thereagainst to hold it against its seat.

When it is desired to open the flapper valve 22, sufficient fluid pressure is imposed on the fluid in the annulus D above the well packer A and between the tubing C and the well casing B. This fluid under pressure can pass around the head 38, which has substantial clearance with the sleeve 17, and through one or more lateral ports 41 provided in the locator sub 37 to the annular space 42 above the piston portion of the apparatus between the inner sleeve 36 and the upper portion of the packer body 10. The pressure will act in a downward direction over

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the piston structure 31 to 35, being effective upon the entire transverse surface of this structure which has an annular area between the periphery of the inner sleeve 36 and the inner wall of the counterbore 20. Such pressure acts in a downward direction on the piston structure and the tubing extension 26, and when it is sufficient to overcome the pressure of the well production, the piston and tubing extension are urged downwardly, shifting the lower end 27 of the tubing extension against the valve head 22 and swinging the latter downwardly about its pivot 24 to the fully open position illustrated in Fig. 1. The limiting of downward movement of the piston structure 31 to 35 and tubing extension 26 is determined by engagement of the inner flange 33 with the external flange 40.

To maintain the valve open, the pressure in the tubing-casing annulus D must be maintained and must exceed the pressure in the production zone, or in the casing immediately below the well packer A, inasmuch as this latter pressure is acting in an upward direction over the pistons 31 to 35 and across the same annular area as the tubing-casing annulus pressure D is acting in a downward direction over the piston. So long as the tubing-casing annulus pressure D exceeds the pressure at the flapper valve head 22, the well production can flow upwardly through the tubing extension 26, inner sleeve 36 and locator sub 37 into the tubing string C, continuing on up through the latter to the top of the well bore.

At any time that the tubing-casing annulus pressure, acting on the upper end of the piston structure 31 to 35, drops below the pressure in the casing at the flapper valve head 22, such latter pressure will act on the piston structure 31 to 35 to shift the extension 26 upwardly within the body 10 and along the inner sleeve 36, until the lower end 27 of the tubing extension is disposed above the valve seat 23, which will permit the spring 25 to swing the flapper head 22 upwardly into engagement with the valve seat 23, to completely shut off the well production.

If the well production is again to flow upwardly through the apparatus into the tubing string C, it is necessary to provide a sufficient pressure in the tubing-casing annulus D to overcome the formation pressure acting on the valve head 22. This tubing-casing annulus pressure acts in a downward direction on the annular piston structure 31 to 35 to shift it and the tubing extension 26 downwardly within the body passage 21 so that the tubing extension again shifts the flapper valve head 22 downwardly about its fulcrum pin 24 to the fully open position disclosed in Fig. 1.

With the apparatus disclosed, a comparatively simple well production shut-off device is provided. By the simple device of relieving the pressure in the tubing-casing annulus D, the well production is caused to automatically close the apparatus against upward flow of fluid. Thus, the operator at the top of the well bore, either directly or through some remote control device, can relieve the pressure in the annulus D, causing the well production pressure to act in an upward direction on the tubing extension 26 and piston structure 31 to 35 and shift the extension upwardly to a position above the valve seat 23, which will allow the valve head 22 to swing upwardly into sealing engagement with the valve seat 23. Assuming the control apparatus to be in the open position disclosed in Fig. 1, if the surface connections are disrupted as by the weather conditions, enemy action, or any other hazard, such disruption of the connection will relieve the pressure in the tubing-casing annulus D and the pressure of the well production will again shift the tubing extension 26 and piston structure 31 to 35 upwardly in the body 10 of the tool, to allow the flapper valve head 22 to swing upwardly into closed engagement against the valve seat 23.

Again assuming the valve apparatus to be in the open condition, if the casing B were to begin leaking above the

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packer A, the pressure in the tubing-casing annulus D would be relieved to the extent at which the well production pressure would predominate and again effect an upward shifting of the tubing extension 26 within the packer body 10, to effect a closing of the valve 22.

Thus, regardless of the cause of the tubing-casing annulus pressure, which acts downwardly on the annular piston structure 31 to 35, diminishing below the well production pressure, acting upwardly on the piston structure, the valve 22 will be caused to close to prevent any further well production from passing upwardly through the well packer A and through the tubing string C. If such flow is to be reestablished, then the tubing-casing annulus pressure must also be reestablished, to effect a downward shifting of the piston structure 31 to 35 and the tubing extension 26 within the packer 10, the lower end 27 of the tubing extension again engaging the valve head 22 and swinging it downwardly away from its seat 23 to the fully open position illustrated in Fig. 1.

The apparatus is comparatively simple, and can be produced at a low cost. It is particularly adaptable for use in well packers that have been previously installed in the well bore, it merely being necessary to insert the tubing extension 26 in the packer body 10 and the piston structure 31 to 35 in sealing relation to the wall of the body counterbore 20. The predominance of pressure in the tubing-casing annulus D, or in the well bore below the well packer A, will determine the position of the tubing-extension 26 and the open or closed condition of the flapper valve head 22 with respect to its seat 23.

A fully open passage is provided through the apparatus disposed within the well packer, there being no restrictions to the flow of fluid through the apparatus. Moreover, such full opening of the passage through the apparatus permits other equipment, such as shaped charges, casing perforators, and the like to be lowered through the apparatus and withdrawn therefrom.

The inventor claims:

1. In apparatus for controlling well production in a well bore: a well packer adapted to be set in the well bore above the point of entry of the well production into the well bore, said packer having a passage therethrough; valve means adapted to close said passage; a tubular member slidable downwardly in said passage into engagement with said valve means to open said valve means, said tubular member being adapted to conduct well production through said packer, said tubular member having fluid operated means thereon; a tubular string adapted to be disposed in the well bore to provide an annulus therewith located around the tubular string and operatively associated with said tubular member to conduct said well production from said tubular member to the top of the well bore; and means for feeding fluid under pressure from the annulus around said tubular string and above said well packer to said fluid operated means to urge said tubular member downwardly in said passage against said valve means to open said valve means.

2. In apparatus for controlling well production in a well bore: a well packer adapted to be set in the well bore above the point of entry of the well production into the well bore, said packer having a passage therethrough and a valve seat at its lower portion surrounding said passage; a valve member movable upwardly into engagement with said seat to close said passage; a tubular member slidable downwardly in said passage into engagement with said valve member to shift said valve member downwardly from said seat, said tubular member being adapted to conduct well production through said packer, said tubular member having fluid operated means thereon; a tubular string adapted to be disposed in the well bore to provide an annulus therewith located around the tubular string and operatively associated with said tubular member to conduct said well production from said tubular member to the top of the well bore; and means for feeding fluid under pressure from the annulus around said

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tubular string and above said well packer to said fluid operated means to urge the tubular member downwardly in said passage against said valve member to disengage said valve member from said seat.

3. In apparatus for controlling well production in a well bore: a well packer adapted to be set in the well bore above the point of entry of the well production into the well bore, said packer including a tubular body having a passage therethrough and a valve seat at the lower portion of said body surrounding said passage; a valve member movable upwardly into engagement with said seat to close said passage; a tubular member slidable downwardly in said passage into engagement with said valve member to shift said valve member downwardly from said seat, said tubular member being adapted to conduct well production through said body, said tubular member having fluid operated means thereon, slidably and sealingly engaging the inner wall of said tubular body; a tubular string adapted to be disposed in the well bore to provide an annulus therewith located around the tubular string and operatively associated with said body and tubular member to conduct said well production from said tubular member to the top of the well bore; and means for feeding fluid under pressure from the annulus around said tubular string and above said well packer to said fluid operated means to urge said tubular member downwardly in said passage against said valve member to disengage said valve member from said seat.

4. In apparatus for controlling well production in a well bore: a well packer adapted to be set in the well bore above the point of entry of the well production into the well bore, said packer including a tubular body having a passage therethrough and a valve seat at the lower portion of said body surrounding said passage; a valve member movable upwardly into engagement with said seat to close said passage; a tubular member slidable downwardly in said passage into engagement with said valve member to shift said valve member downwardly from said seat, said tubular member being adapted to conduct well production through said body, said tubular member having fluid operated means thereon slidably and sealingly engaging the inner wall of said tubular body; a tubular string adapted to be disposed in the well bore to provide an annulus therewith located around the tubular string and operatively associated with said body and tubular member to conduct said well production from said tubular member to the top of the well bore; said tubular string having a port for directing fluid from the annulus around said tubular string and above said well packer to said fluid operated means to urge said tubular member downwardly in said passage against said valve member to disengage said valve member from said seat.

5. In apparatus for controlling well production in a well bore: a well packer adapted to be set in the well bore above the point of entry of the well production into the well bore, said packer including a tubular body having a passage therethrough and a valve seat at the lower portion of said body surrounding said passage, said body having a counterbore in its upper portion; a valve member movable upwardly into engagement with said seat to close said passage; a tubular member slidable downwardly in said passage into engagement with said valve member to shift said valve member downwardly from said seat, said tubular member being adapted to conduct well production through said body, said tubular member having fluid operated means slidably and sealingly engaging the wall of said counterbore; a tubular string adapted to be disposed in the well bore to provide an annulus therewith located around the tubular string and operatively associated with said body and tubular member to conduct said well production from said tubular member to the top of the well bore; and means for feeding fluid under pressure from the annulus around said tubular string and above said well packer to said fluid operated means to urge the tubular member downwardly in said passage

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against said valve member to disengage said valve member from said seat.

6. In apparatus for controlling well production in a well bore: a well packer adapted to be set in the well bore above the point of entry of the well production into the well bore, said packer including a tubular body having a passage therethrough and a valve seat at the lower portion of said body surrounding said passage, said body having a counterbore in its upper portion; a valve member movable upwardly into engagement with said seat to close said passage; a tubular member slidable downwardly in said passage into engagement with said valve member to shift said valve member downwardly from said seat, said tubular member being adapted to conduct well production through said body, said tubular member having fluid operated means slidably and sealingly engaging the wall of said counterbore; a tubular string adapted to be disposed in the well bore to provide an annulus therewith located around the tubular string and operatively associated with said packer to conduct said well production from said tubular member to the top of the well bore, said tubular member slidably and sealingly engaging said tubular string; and means for feeding fluid under pressure from the annulus around said tubular string and above said well packer to said fluid operated means to urge said tubular member downwardly in said passage against said valve member to disengage said valve member from said seat.

7. In apparatus for controlling well production in a well bore: a well packer adapted to be set in the well bore above the point of entry of the well production into the well bore, said packer including a tubular body having a

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passage therethrough and a valve seat at the lower portion of said body surrounding said passage, said body having a counterbore in its upper portion; a valve member movable upwardly into engagement with said seat to close said passage; a tubular member slidable downwardly in said passage into engagement with said valve member to shift said valve member downwardly from said seat, said tubular member being adapted to conduct well production through said body, said tubular member having fluid operated means slidably and sealingly engaging the wall of said counterbore; a tubular string adapted to be disposed in the well bore to provide an annulus therewith located around the tubular string and engaging said body and having a sleeve extending within said tubular member in slidable sealing relation therewith; and means for feeding fluid under pressure from the annulus around said tubular string and above said well packer to said counterbore for action upon said fluid operated means to urge said tubular member downwardly in said passage against said valve member to disengage said valve member from said seat.

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