

[54] **WELL VALVE APPARATUS** 2,998,070 8/1961 Tamplen et al. 166/72
 [75] **Inventor: James D. Mott, Houston, Tex.** 3,035,808 5/1962 Knox 166/72
 R16,577 3/1927 Crowell 166/314

[73] **Assignee: Hydril Co.**

[22] **Filed: Mar. 18, 1974**

Primary Examiner—James A. Leppink
Attorney, Agent, or Firm—Pravel & Wilson

[21] **Appl. No.: 451,976**

[52] **U.S. Cl.** 166/72; 166/189; 166/224 A

[51] **Int. Cl.²** **E21B 43/12**

[58] **Field of Search** 166/72, 224 A, 313, 314,
 166/189

[57] **ABSTRACT**

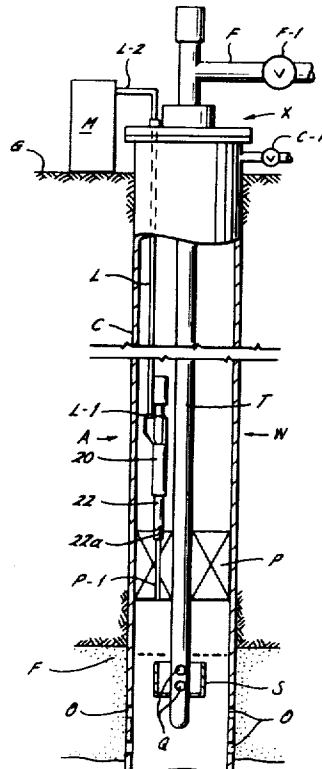
A remote controlled full opening ball-type valve for mounting at a subsurface location in a well with a well packer in a well annulus between the production tubing and well casing for providing a flow path through an opening of the packer and the well annulus for the well produced gases separate from the flow path through the production tubing for the well produced liquids. The valve is preferably arranged to fail-safe and shut-in gas flow through the annulus when control fluid pressure communicated to the valve from the surface is reduced for any reason.

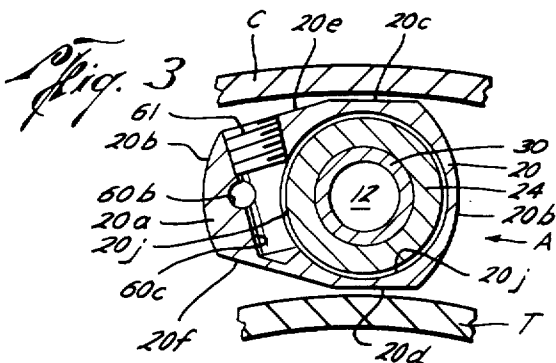
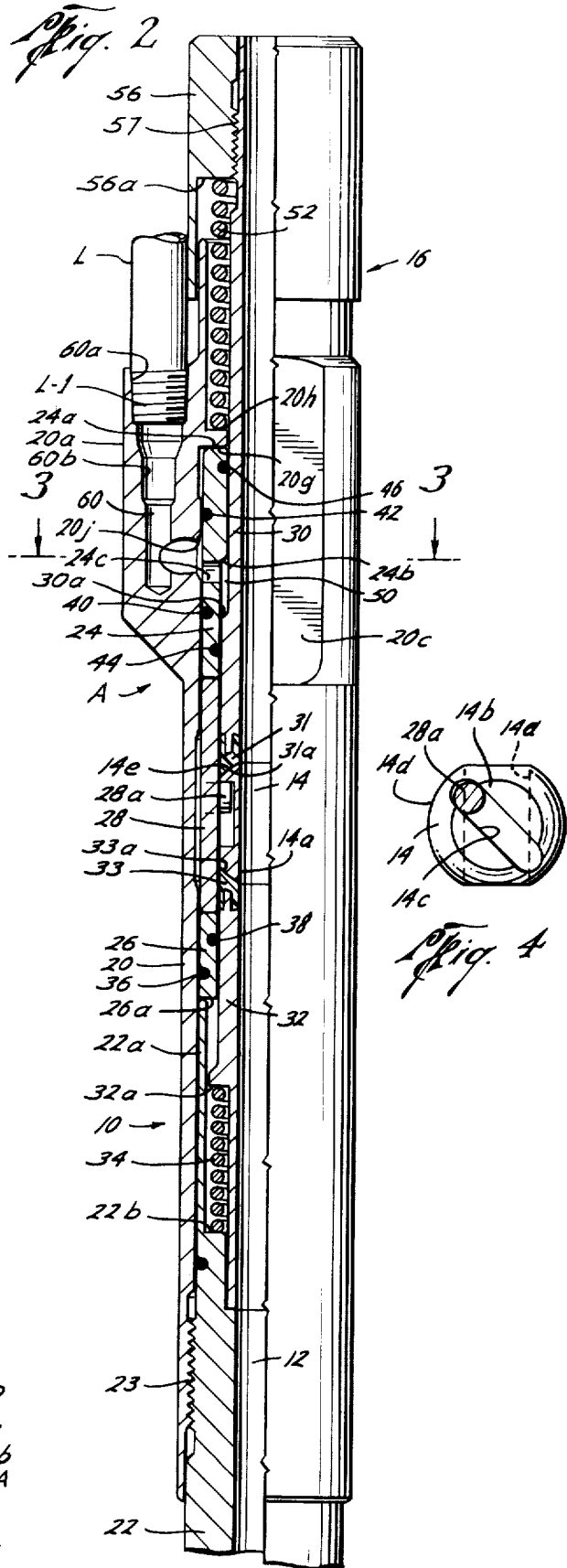
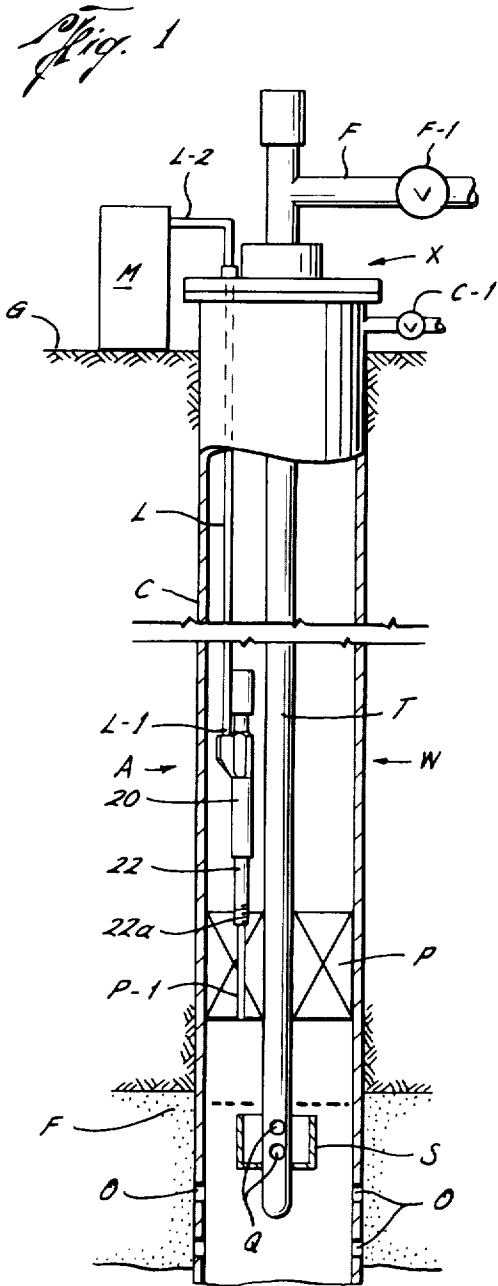
13 Claims, 4 Drawing Figures

[56] **References Cited**

UNITED STATES PATENTS

49,778	9/1865	Mills	166/189
203,044	4/1878	Hoadley.....	166/189
454,432	6/1891	Heed.....	166/314
1,050,689	1/1913	Pierce.....	166/189
2,894,715	7/1959	Bostock	166/72





WELL VALVE APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to the field of well valve apparatus and more particularly to valves for controlling flow through an opening formed through a well packer.

Many wells, primarily in California or offshore California, have had to be pumped to recover the liquid well fluids even though some well gases were also provided by the producing formation of the well. While these gases were produced by the formation in insufficient quantities and pressure to force or flow the well liquids to the surface, the produced gases were present in sufficient quantities to hinder and interrupt pumping operations by effecting pump cavitation or a form of vapor lock in piston pumps to interrupt production of the well liquids.

SUMMARY OF THE INVENTION

This invention relates to a new and improved well valve apparatus.

A remote controlled fail-safe full opening ball-type valve for mounting with a well packer in the well annulus between the production tubing and well casing for controlling flow of well gases through an opening in the packer to the surface through the well annulus. The valve provides a straight through flow path for the well gases when control fluid pressure supplied to the valve through a separate control fluid conduit is increased. The valve body is formed or shaped to be operably disposed on the packer between a closely spaced production tubing and well casing.

An object of the present invention is to provide a new and improved well valve apparatus.

A further object of the present invention is to provide a new and improved well valve apparatus for controlling flow of well fluids through a well packer.

Yet another object of the present invention is to provide a new and improved well apparatus of unique shape to enable the valve apparatus to be operably disposed between a closely spaced production tubing and well casing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view, partially in section, illustrating the well valve apparatus of the present invention operably disposed at a subsurface location in a well;

FIG. 2 is a side view, partially in section, of the well valve apparatus of the present invention;

FIG. 3 is a view taken along line 3—3 of FIG. 2; and

FIG. 4 is a side view illustrating in greater detail the relationship of the ball-type closure member and the engaging pivot pins.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The valve apparatus of the present invention, generally designated A in the FIGS., is illustrated in FIG. 1 operably positioned in a well W below the ground surface G. The valve apparatus A is mounted on a packer P which effects a fluid tight annular seal between the well casing C and the well or production tubing T for directing flow of well fluids through the opening or bore of the production tubing T to the surface G in the usual manner. The casing C is provided with a plurality of perforations or openings O below the annular seal effected by the packer P for enabling flow of well fluids

from the producing formation F into the casing C in the well known manner.

In the normal and known practice, the produced well fluids either flow or are pumped through the production tubing T to the well head valve manifold system or Christmas tree X at the surface G where they are directed through a flow line F to a desired location (not illustrated) for storage or processing. A valve, indicated at F-1, may be mounted in the flow line F or a master valve (not illustrated) may be used to shut-in the well W of the surface G when desired. The Christmas tree X also provides a valve, designated at C-A for shutting-in the well casing C when desired. The Christmas tree X also serves to provide a flow blocking seal between the well casing C and the production tubing T at the surface in the usual manner.

The producing formation F of some wells W produce quantities of both well gases and well liquids, but the formation pressure is insufficient to flow the well liquids and gases to the surface G. To move or flow the well liquids from the producing formation F through the production tubing T in the flow line F a suitable pump means (not illustrated) is employed. If not isolated from the pump means the well gases from the formation F within the well casing C eventually interfere with the liquid pumping operations in some manner depending upon the type of pump means used. Some examples of such interference may be pump cavitation, loss of pump suction, or a form of gas or vapor lock, but such examples should be considered as typical and not inclusive.

As illustrated in FIG. 1, the valve apparatus A is preferably mounted directly with the packer P for controlling flow of well fluids through an opening P-1 of the packer P. When the valve apparatus A is in the open position well gases from the producing formation F flow through the opening P-1 into the well annulus between the production tubing T in the well casing C above the packer P and from the well W through the valve indicated at C-1. To assist in directing the produced well gases through the opening P-1, the lower end of the production tubing T may be closed and a number of openings Q formed through the wall of the production tubing T. Also, a shield means S sealed to production tubing below the opening Q and preferably extending upwardly to a location above the opening Q may be employed adjacent the plurality of openings Q for directing the flow of well gases and liquids to a location above the openings Q. The lighter well gases will of course continue upwardly through the opening P-1 while the heavier well liquids will flow downwardly by gravity inside the shield means S towards the plurality of openings Q into the production tubing T for movement to the surface G. As will be set forth in greater detail hereinafter, the valve apparatus A is remotely controlled from the surface using a control line L which is connected at a lower end L-1 to the valve apparatus A and which extends upwardly in the well annulus through the Christmas tree X for connection at an upper end L-2 to a control means, designated M, at the surface G.

As illustrated in greater detail in FIG. 2, the valve apparatus A of the present invention includes a valve body or housing, generally designated 10, having a straight through fluid flow passage or bore 12 formed therethrough. The housing 10 is preferably mounted directly with the packer P with the bore 12 of the hous-

ing 10 in flow communication with the opening P-1 of the packer P but of course could be spaced from the packer P. The valve apparatus A further includes a movable valve closure element or member 14 disposed in the bore 12 and means, generally designated 16, operable with the valve closure member 14 for effecting movement of the valve closure member 14 to and from an open position for enabling flow of fluids through the bore 12 and a closed position for blocking flow of well fluids through the bore 12.

The valve body 10 is disposed in the well annulus above the packer and between the well casing C and the production tubing T. The valve body 10 is a substantially tubular unit having enlarged portion shaped or formed to fit in a minimum concentric spacing between the casing C and the production tubing T. For ease of assembly the tubular valve body 10 is preferably formed by an upper sleeve 20 and a lower sleeve 22 which are secured together by suitable means, such as threaded engagement at 23. Suitable anti-rotation pins (not illustrated) may be provided to prevent inadvertent disengagement of the sleeves 20 and 22. In the illustrated embodiment the lower sleeve 22 is provided with threads 22a adjacent the lower end thereof to threadedly engage in the opening P-1 of the packer P for securing the valve body 10 to the packer P with the bore 12 of the valve body 10 in flow communication with the opening P-1 of the packer P (FIG. 1).

The sleeve member 20 forms an enlarged outer portion 20a of the valve body 10 intermediate the ends thereof which is arranged to receive and secure to the valve body 10 the lower end L-1 of the control line L. In the preferred embodiment, the enlarged portion 20a is formed by a cylindrical tubing section mounted in eccentric relationship to the bore 12 defining remainder of the sleeve 20 and having opposite sides thereof removed by milling or any other suitable process in order that the enlarged portion 20a provides an exterior shape to fit between the closely spaced production tubing T in the well conduit C. As best illustrated in FIG. 3 the outer circular surface 20b of the eccentric mounted cylinder forming the enlarged portion 20a is machined or shaped on opposite sides to provide parallel flat surfaces 20c and 20d. In addition, the flat surfaces 20c and 20d may be further formed or machined by tapering surfaces 20e and 20f, respectively, to provide additional clearance between the production tubing T and the well casing C to prevent snagging on the well casing C as the valve apparatus A is lowered in the well W during installation. The enlarged portion 20a serves to enable the remainder of the valve body 10 to be made of thinner or lighter wall thickness and thus a more compact valve body 10 is provided. Not only does enlarged portion 20a enable the providing of a greater flow area through the bore 12, but by properly shaping or forming the enlarged portion 20a to fit closely between the production tubing T in the well casing C the necessity to run oversized casing C for a desired size of production tubing T is minimized. For instance, using the valve apparatus A of the present invention, it is possible to produce through 2-3/8 inch tubing T in a 5 inch casing C.

The valve body 10 further includes a pair of spaced sealing rings 24 and 26 which are located above and below the split valve closure mounting member 28 surrounding the valve element 14. The seal rings 24 and 26 and the split member 28 are secured in the bore 12

of the valve body 10 against downward movement by an upward extension 22a of the sleeve 22 engaging the lower annular shoulder 26a of the lower seal ring 26. The sleeve 20 is provided with a downwardly facing annular shoulder 20g which engages an upper annular shoulder 24a of the sealing ring 24 to block upward movement of the seal rings 24 and 26 and the split member 28 in the bore 12.

The valve closure member or element 14 is preferably a substantially ball or spherical shaped element having a full opening flow port 14a formed therethrough. The ball 14 is rotatable between a first or upper closed position with the opening 14a disposed traverse to the bore 12 and a second or lower opened position with the flow port 14a in aligned communication with the bore 12 (FIG. 2) for enabling flow of fluid through the bore 12. The ball 14 includes a pair of parallel surfaces or flats 14b formed on opposite sides of the ball 14 with the flats 14b substantially parallel to the longitudinal axis of the flow port 14a. Extending across the flats 14b in diagonal or spaced relationship with the axis of the flow port 14a is a connecting slot or recess 14c. The ball 14 is located adjacent the split cage member 28a in order that inwardly projecting aligned pivot pins 28a which are located in eccentric relationship with the ball 14 extend within the recesses or grooves 14c of the ball for effecting pivoting or rotational movement of the ball 14 when the ball 14 is moved longitudinally through the bore 12 from the upper or closed position to the lower or open position. For a more detailed description and illustration of the rotation of the ball 14, reference is hereby made to U.S. Pat. No. 3,762,471 and especially to FIGS. 10-15 thereof and which disclosure is incorporated herein by reference thereto.

The means, commonly designated 16, for effecting operating movement of the ball 14 includes spaced upper and lower operator sleeves 30 and 32, respectively and the cage sleeve 28. The upper operator sleeve 30 carries or mounts a seat ring 31 adjacent the ball 14 for effecting an annular fluid tight seal with the ball 14. The annular seat ring 31 forms an arcuate sealing surface 31a which sealingly engages the spherical surface 14d of the ball 14 for effecting the seal therebetween. The lower sleeve 32 mounts a seat ring 33 having an arcuate 33a engaging the spherical surface 14d of the ball 14 for effecting a fluid tight seal with the ball. The seals 31 and 33 cooperate with the ball 14 in the closed position to block leakage or flow of fluid through the bore 12. The sleeves 30 and 32 are longitudinally movable in the bore 12 between the first or upper valve closing position and the second or lower valve opening position (FIG. 2).

The lower sleeve 32 is provided with a downwardly facing annular shoulder 32a which engages a spring means 34. The spring means 34 is disposed in annular chamber formed between the sleeve 32 in the upward extension 22a of the lower housing sleeve 22. The spring means 34 engages an upwardly facing annular shoulder 22b of the lower housing sleeve 22 for fixedly mounting the spring means 34 with the housing 10. The spring means 34 thus serves to provide a means for urging the sleeve 32 to the upper position for effecting closing rotation of the ball 14 about the pivot pins 28a.

The lower seal ring 26 carries a pair of O-rings 36 and 38 for blocking leakage of fluid between the sealing ring 26 and the housing sleeve 20 and the sliding sleeve 32. The downwardly facing annular space on the sleeve

32 between the seal with the sleeve 32 effected by the O-ring 38 and the seat ring 33 with the ball 14 provides a pressure responsive surface for urging the sleeve 32 upwardly in response to well pressure in the bore 12 below the ball 14 and providing means for urging the ball 14 to the closed position.

The upper seal ring 24 carries a pair of spaced O-rings 40 and 42 for effecting spaced annular fluid tight seals with the tubular member 20. The seal ring 24 also mounts a second pair of spaced O-rings 44 and 46 for effecting sliding annular fluid passage blocking seals between the seal ring 24 and the sliding upper operator sleeve 30.

The fixed upper locking ring 24 forms a downwardly facing annular shoulder 24b between the seals effected by the O-rings 44 and 46 with the upper operator sleeve 30. The movable sleeve 30 provides or forms an upwardly facing annular shoulder 30a which engages the downwardly facing shoulder 24b for providing an upper movement limit stop for the sleeve 30, the ball 14 and the lower sleeve 32 when they move to the upper position. The seal ring 24 and the longitudinally movable upper operator sleeve 30 also define an annular expandible chamber 50 between the seal effected by the O-rings 44 and 46. Fluid pressure communicated or introduced into the chamber 50 will urge on the pressure responsive surface 30a of the upper operator sleeve 30 for moving the upper sleeve 30, the ball 14 and the operator sleeve 32 to the lower position for effecting opening rotation of the ball 14. The fluid pressure in the chamber 50 moves the ball 14 to the open position when the fluid pressure in the chamber 50 overcomes well pressure on sleeve 32, the spring means 34 and a spring means 52 mounted above the sealing ring 24. The spring means 52 is mounted at its lower end with an upwardly facing annular shoulder 20h of the sleeve 20 while the upper end engages a downwardly facing annular shoulder 56a of a spring retainer 56 which is secured to the upper operator sleeve 30 by suitable means, such as threaded engagement at 57. The spring means 52 thus serves to move the upper operator sleeve 30 to the upper position when the pressure in the expandible chamber 50 is reduced and enables the lower spring means 34 and the well pressure to move the lower operator sleeve 32 upwardly for effecting closing rotation of the ball 14.

The upper sealing ring 24 includes a flow port 24c formed therethrough for communicating the expandible chamber 50 with a control fluid passage 60 formed in the clearance enabling shaped enlarged portion 20a of the sleeve 20. The control fluid passage 60 is provided with threads 60a for threaded engagement of the lower end L-1 of the control fluid conduit L and placing the control fluid conduit L and the control fluid passage 60 in communication. The control fluid conduit 60 is provided with a downwardly extending portion 60b which extends downwardly to a location opposite the flow port 24c of the upper sealing ring 24. As illustrated in both FIGS. 2 and 3, an annular recess 20j is formed in the tubular member 20 adjacent the exterior of flow port 24c of the upper sealing ring 24. To provide communication between the vertical passage 60b and the annular recess 20j a horizontal port 60c is drilled or formed at an angle in the shaped enlarged portion 20a for communicating therebetween. Suitable means, such as threaded plug 61 is subsequently installed to enclose or seal the control fluid passage 60

from the well annulus. With this arrangement, increasing the pressure of the fluid in the conduit L at the surface will also increase the pressure of the fluid in the chamber 50 for effecting opening rotation of the ball 14 for enabling flow through the bore 12. Decreasing the pressure in the conduit L at the surface G reduces the pressure in the chamber 50 and enables the spring means 34 and well pressure to effect closure of the ball 14. The valve apparatus A is therefore fail-safe in that loss of control fluid pressure in the conduit L enables the valve to close and shut-in the well W at the subsurface location.

The upper end of the control fluid conduit L is schematically illustrated connected to a control fluid unit or means M for providing the control fluid pressure signal into the expandible chamber 50 for effecting opening rotation of the valve. Such control units are well known in the art and may be either manually operated or may be automatically responsive to certain well conditions for shutting-in the well. For a more complete description of such a control unit means M reference is made to U.S. Pat. No. 3,035,808 to Knox and No. 2,998,070 to Tamplen, et al. for more complete disclosure of such automatic control means which is by reference incorporated herein.

OPERATION

When it is desired to complete the well W using the valve apparatus A of the present invention, the valve apparatus A is secured to the packer P using threads 22a prior to connecting the packer P with the production tubing T. The lower end L-1 of the control fluid conduit L is then connected to the enlarged portion 20a of the sleeve 20 by threaded engagement at 60a of the control fluid passage 60. The production tubing T, the packer P and the valve apparatus A are then lowered down into the well W through the casing C to the desired subsurface operating location and the packer is set in the usual manner.

All other operations and procedures necessary to complete the well W are then accomplished including sealing about the control fluid conduit L where it extends through the Christmas tree X at the surface G and connecting the upper end L-2 of the control fluid conduit L with the control fluid pressure means M. When it is desired to produce from the well W the control fluid pressure in the conduit L is increased by the use of the control fluid pressure means M. This increase pressure is communicated from the control fluid conduit L through the flow passage 60 into the expandible chamber 50 for urging the operator sleeves 30 and 32 to move downwardly and rotate open the ball 14. Gases from the formation O within the well casing C are then enabled to flow through the opening P-1 of the packer P and through the bore 12 into the well annulus above the packer P and from the well casing C through the valve indicated at C-1. With the ball 14 in the open position pumping of the produced liquids through the production tubing T may then be accomplished without the hazard of the well gases hindering the usual pumping operations.

When it becomes desirable to shut-in the well at the subsurface location-either manually or automatically-the control fluid pressure signal introduced into the control fluid conduit L at the surface by the control unit means M is reduced and the control fluid conduit L is vented to enable the spring means 34 to rotate the

ball 14 to the closed position for shutting-in the well.

The shape of the enlarged portion 20a of the valve body 10 enabling the close fitting relationship between the production tubing T and the casing C is significant in that it prevents snagging of the control fluid conduit or the valve apparatus A when the packer P and the valve apparatus is being run in or removed from the well W and that it requires the providing of only a minimum clearance between the production tubing and the well casing C for the valve A. The enlarged portion 20a also enables an overall thinner wall thickness for the valve A and thereby reducing the external dimensions of the valve and enhancing the clearance. The enlarged portion serves also for protectively and securely connecting with lower end L-1 of the control fluid conduit L to minimize control fluid leaks and enable reliable remote control operation of the valve apparatus A from a control signal provided by the control fluid pressure means M at the surface G.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape and materials as well as in the details of the illustrated construction may be made without departing from the spirit of the invention.

I claim:

1. Flow control apparatus for use at a subsurface location in a well producing gases in sufficient quantities to hinder pumping of the well liquids to the surface by providing a separate valve controlled flow path to the surface for the well gases, including:

a packer adapted for securing with a well tubing for effecting an annular fluid tight seal between a well casing and the well tubing and having a central flow passage formed through the packer communicating with the well tubing for enabling flow of the well liquids through said packer, said packer having a second opening formed therethrough spaced from and parallel to said central flow passage for enabling flow from below the packer to the surface through said well casing, said second opening being of smaller flow area than said central flow opening and disposed outwardly of said central flow passage;

valve means including a substantially tubular valve body having a longitudinal bore formed therethrough and connected with said packer to be positioned parallel to the well tubing between the well tubing and the well casing with said bore in flow communication with said second opening of said packer and having a movable valve closure member disposed in said bore for movement to and from an open position for enabling flow through said second opening of said packer and a closed position for blocking flow through said second opening of said packer, said valve means including means for urging said valve closure member to the closed position with said valve closure member movable to the open position to enable flow responsive to a control signal communicated to the valve from the surface exteriorly of the well tubing; and

said tubular valve body having an enlarged eccentric outer portion shaped for positioning in close fitting relationship between the well casing and the well tubing for forming an upwardly facing connection for receiving the control signal from the surface

and enabling use of a more compact tubular valve body for positioning in the well between the well casing and well tubing.

2. The apparatus as set forth in claim 1, including: means for urging said valve closure member to the closed position, said control signal overcoming said means for urging to move said valve closure member to the open position.

3. The apparatus as set forth in claim 2, wherein: said means for urging including well fluid pressure.

4. The apparatus as set forth in claim 2, wherein: said means for urging including spring means mounted with said valve body for urging said valve closure member to the closed position.

5. The apparatus as set forth in claim 2, including: a control fluid conduit connected at one end with said enlarged portion valve body and connected at the other end to a means for providing a controlled source of fluid pressure at the surface, the fluid pressure in said control fluid conduit communicated to said valve for overcoming said means for urging to move said valve closure member to the open position.

6. The apparatus as set forth in claim 5, wherein: said means for providing a controlled source of fluid pressure is manually operable to enable closing of said valve closure member.

7. The apparatus as set forth in claim 5, including: said means for providing a controlled source of fluid pressure pressure is automatically operable to enable closing of said valve closure member.

8. A valve apparatus for use with a packer mounted with a well tubing at a subsurface location in a well to control flow of well fluids through a vent opening formed through the packer including:

a tubular valve body adapted for mounting with the packer in the well annulus above the packer between the well tubing and a well casing, said valve body having a longitudinal bore extending therethrough in flow communication with the vent opening of the packer;

a valve closure member mounted with said valve body for movement to and from an open position for enabling flow of well fluids through said bore and the vent opening of the packer and a closed position for blocking flow of fluids through said bore and the vent opening of the packer;

means operably connected with said valve closure member for effecting movement of said valve closure member to and from the open and closed position, said means for effecting movement of said closure member including means for urging said valve closure member to the closed position, and means for moving said closure member to the open position in response to a control signal communicated to the valve from the surface exteriorly of the well tubing; and

said tubular valve body having an enlarged outer portion formed of a cylindrical section disposed intermediate the ends of said tubular valve body and in eccentric relationship with said tubular valve body for forming an upwardly facing connection for receiving the control signal from the surface to enable use of a smaller tubular valve body, said cylindrical section having portions of opposite sides removed for positioning in close fitting relationship between the well casing and the production tubing.

9

9. The apparatus as set forth in claim 8, including:
 said means for effecting movement of said valve closure member including an operator member disposed in said flow passage and movable to and from a first position for enabling closing movement of said valve closure member and a second position for moving said valve closure member to the open position;
 said operator member and said valve body forming an expansible chamber therebetween, said operator member having a pressure responsive surface for moving said operator member from the first position to the second position in response to the fluid pressure in said expansible chamber overcoming said means for urging;
 a control fluid conduit having a lower end connected with said valve body and in communication with said expansible chamber, said control fluid conduit having an upper end connected with a source of control fluid; and
 means for controlling the pressure of the control fluid communicated into said expansible chamber wherein said valve is controlled,

10. The apparatus as set forth in claim 8, wherein:
 said valve body is a substantially tubular unit having an enlarged outer portion formed thereon, said en-

10

larged outer portion shaped for positioning in close fitting relationship between the production tubing and the well casing.

11. The apparatus as set forth in claim 8, wherein:
 said enlarged portion having means for connecting with the lower end of a control fluid conduit from the surface for controlling operation of the valve apparatus.

12. The apparatus as set forth in claim 8, wherein:
 said means for effecting movement including a pair of spaced operator sleeves disposed in said flow passage on opposite sides of said valve closure member with each of said operator sleeve mounting a seat for sealing engagement with said valve closure member to block passage of fluid between said seats and the valve closure member.

13. The apparatus as set forth in claim 12, wherein:
 said valve closure member is substantially in the shape of a ball having a flow port formed therethrough, said ball member rotating to place said flow port in flow communication with the flow passage to enable flow therethrough and to place said flow port out of flow communication with the flow passage to cooperate with said seats for blocking flow of fluid through said flow passage.

* * * * *

30

35

40

45

50

55

60

65