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Hill

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[45] **Feb. 26, 1974**

[54] **SURFACE CONTROLLED SUBSURFACE SAFETY VALVE**

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[73] Assignee: **Esso Production Research Company,** Houston, Tex.

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[21] Appl. No.: **294,399**

[52] **U.S. Cl.** ..... **166/64,** 166/224 S

[51] **Int. Cl.** **E21b 43/00**

[58] **Field of Search** ..... 166/64, 67, 224, 224 S, 315

[56] **References Cited**

UNITED STATES PATENTS

3,375,874	4/1968	Cherry et al.	166/224 S X
3,007,524	11/1961	Pistole et al.	166/224 S X
3,002,566	10/1961	Bostock	166/224 R
3,411,576	11/1968	Taylor	166/64 X

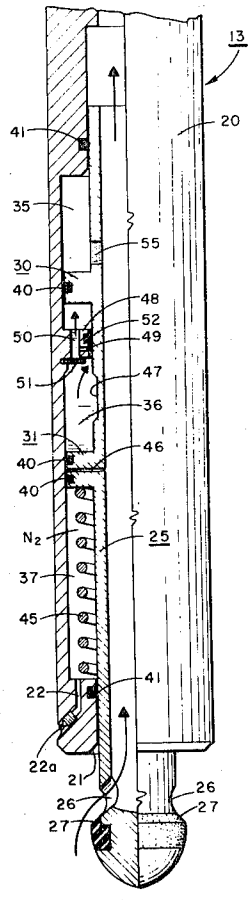
Primary Examiner—H. Hampton Hunter

Attorney, Agent, or Firm—John S. Schneider

[57] **ABSTRACT**

A surface controlled subsurface safety valve is positioned in a well production tubing and an adjustable choke is installed in the surface production tubing. The safety valve is operated by the absolute pressure of the production fluids in the well tubing. The adjustable choke is controlled by a timer which periodically cycles the choke to reduce the flow area available for production of well fluids for a predetermined short period of time. The reduction in flow area causes a corresponding build up of pressure in the surface tubing which is transmitted down the well tubing to the subsurface valve. Biasing means urges the valve to its closed position while tubing pressure urges the valve to its open positions. During normal well flowing conditions the force of the tubing pressure is less than the force of the biasing means and the valve, while remaining fully open is moved by the biasing means towards its closed position. Such movement is retarded by a dash pot arrangement in the valve. Means are provided in the valve to bypass the dash pot and cause rapid closure of the valve when the valve has reached a predetermined point towards its closed position. Under normal operations before the valve reaches the point of rapid closure the tubing pressure force at the valve is increased substantially over the force of the biasing means and the valve is moved rapidly to its initial open position. The increase in tubing pressure at the valve results from reducing the flow area by means of the adjustable choke in the surface tubing.

17 Claims, 5 Drawing Figures



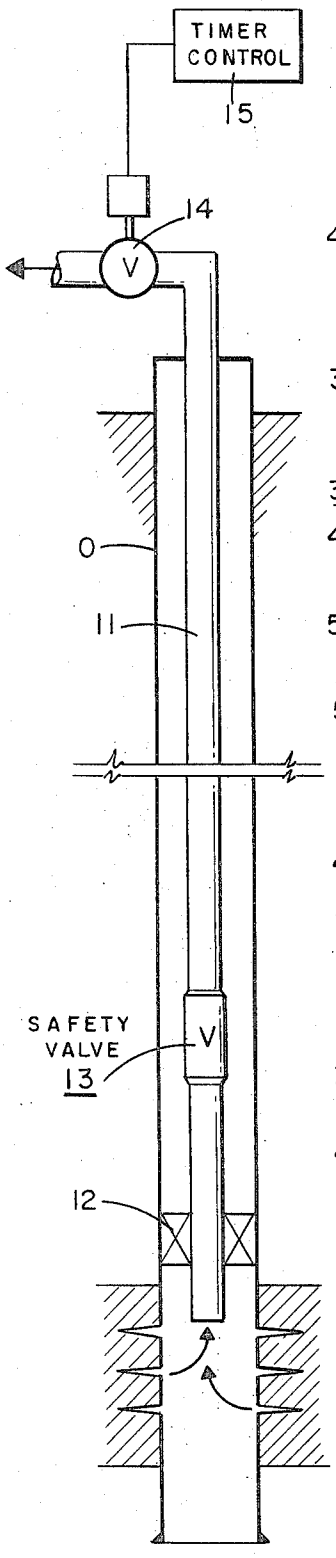


FIG. 1.

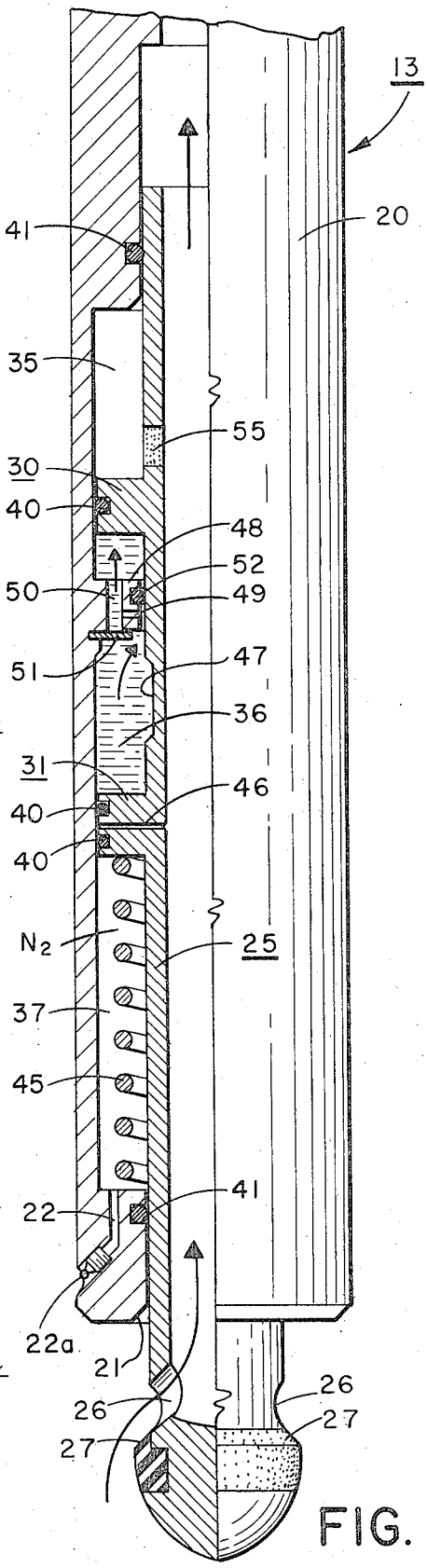


FIG. 2.

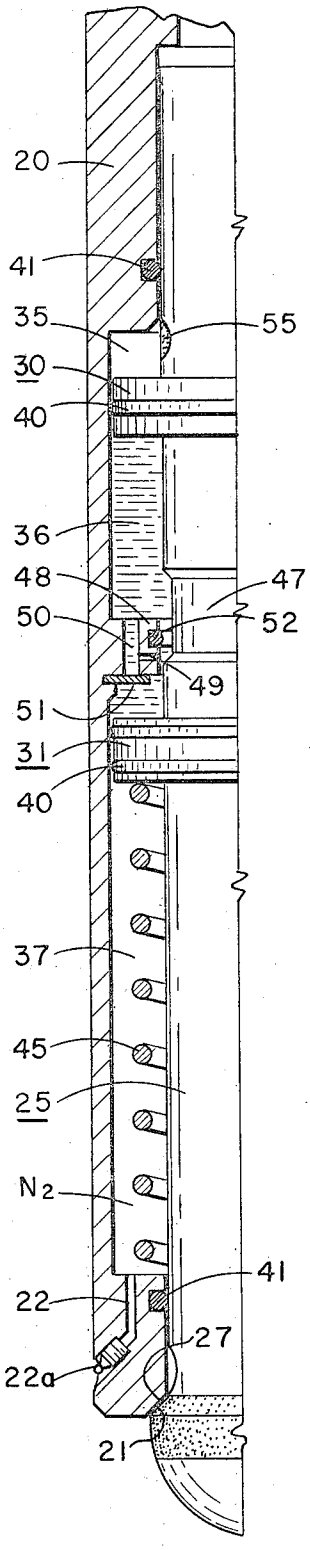


FIG. 3.

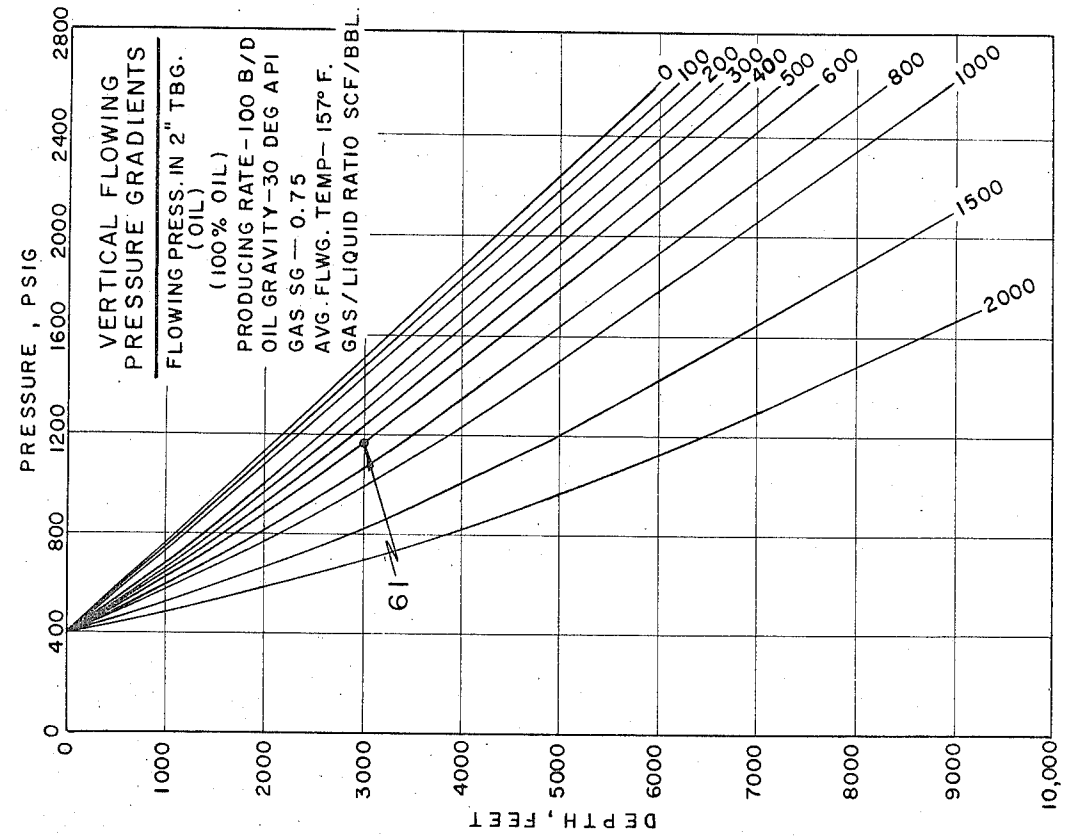

VERTICAL FLOWING
PRESSURE GRADIENTS
FLOWING PRESS. IN 2" TBG.
(OIL)
(100% OIL)
PRODUCING RATE-100 B/D
OIL GRAVITY-30 DEG API
GAS SG — 0.75
AVG. FLWG. TEMP- 157° F.
GAS / LIQUID RATIO SCF/BBL.
0
100
200
300
400
500
600
800
1000
1500
2000
61
PRESSURE, PSIG
0
400
800
1200
1600
2000
2400
2800
DEPTH, FEET
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000

FIG. 5.

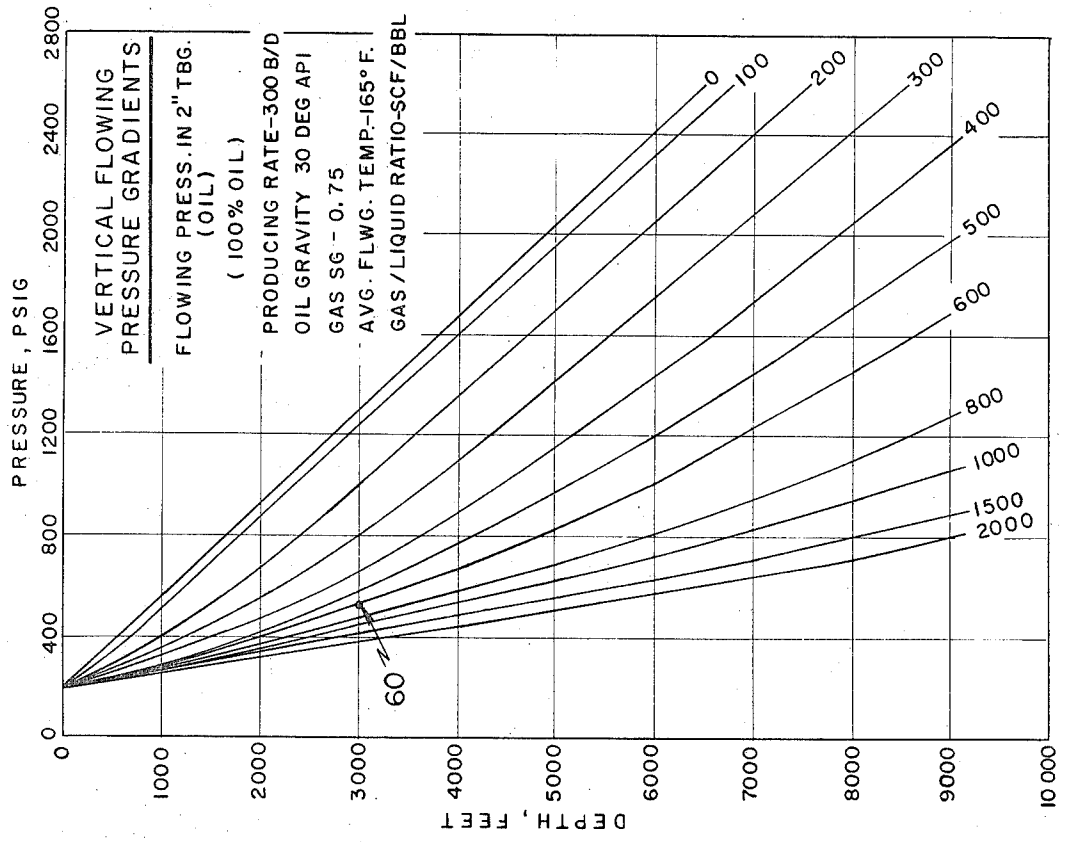

VERTICAL FLOWING
PRESSURE GRADIENTS
FLOWING PRESS. IN 2" TBG.
(OIL)
(100% OIL)
PRODUCING RATE-300 B/D
OIL GRAVITY 30 DEG API
GAS SG - 0.75
AVG. FLWG. TEMP-165° F.
GAS / LIQUID RATIO-SCF/BBL
0
100
200
300
400
500
600
800
1000
1500
2000
60
PRESSURE, PSIG
0
400
800
1200
1600
2000
2400
2800
DEPTH, FEET
1000
2000
3000
4000
5000
6000
7000
8000
9000
10 000

FIG. 4.

SURFACE CONTROLLED SUBSURFACE SAFETY VALVE

BACKGROUND OF THE INVENTION

The present invention concerns a subsurface safety valve for controlling the flow of well fluids, particularly oil and/or gas produced from subsurface formations.

Surface controlled subsurface safety valves offer advantages over velocity actuated safety valves. These advantages include in-place testability, capacity production, and positive control from the surface. However, despite its advantages over velocity actuated safety valves the common hydraulic surface controlled valve, in which hydraulic operating fluid is supplied to a subsurface valve from the surface through exterior small diameter tubing or concentric larger diameter pipe, also has a disadvantage in its use in that such a valve cannot be economically installed on many existing well completions because the well tubing may be cemented in place or be otherwise unmovable except through costly and high risk means. The present valve does not require an exterior small diameter tubing or concentric larger diameter pipe or movement of the well tubing and therefore overcomes the inherent disadvantages in the hydraulic surface controlled valve.

SUMMARY OF THE INVENTION

Briefly, the apparatus of the invention comprises a subsurface safety valve for use in controlling flow of well fluids through well tubing or pipe and includes a valve housing and a flow tube arranged in the valve housing. The flow tube is movable between a first position in which well fluids are prevented from flowing through the flow tube and well tubing and a second position in which the well fluids are permitted to flow through the flow tube and well tubing. The valve also includes biasing means for urging the flow tube to its first position as well as means for retarding movement of the flow tube in its movement toward the first position thereof. The absolute pressure of the well fluids in the well tubing acts on the flow tube to move the flow tube, the flow tube being moved towards its second position against the bias of the biasing means when the absolute pressure of the well fluids exceeds a predetermined amount. Periodically, the flow of well fluids is choked momentarily at the surface by means of a time adjustable choke which causes a pressure pulse to travel down the well tubing to the valve. The pressure pulse is at least equal to the predetermined absolute pressure necessary to move the flow tube to its second position. The adjustable choke is timed to permit the flow tube to move slowly from its second position towards its first position for a selected period of time. Then, before the flow tube reaches its first position the flow tube is returned to its second position under normal operations. The valve will close if the pressure pulse is not sent from the adjustable choke to the valve. After the valve is closed it can be reopened by increasing the well tubing pressure in amounts sufficient to overcome the bias of the biasing means and move the flow tube from its first position to its second position. The pulsing cycles are then repeated and the flow of fluids through the well tubing is unimpeded during normal operations.

In the operation of the subsurface valve of the present invention the flow of fluids from the well tubing is periodically reduced momentarily at the surface to cause a pressure pulse to travel down the well tubing from the surface to the subsurface valve. The increased absolute pressure at the valve resulting from the pressure pulse forces the valve to a fully open position. Under normal flow conditions the force of the absolute pressure at the valve is less than the force of biasing means tending to close the valve. Thus the valve moves towards closure under normal flow conditions while remaining fully open for a selected time period. Prior to closure of the valve the increased absolute pressure at the valve caused by reducing the flow of fluids at the surface causes the valve to reset to its initial open position.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a subsurface safety valve in accordance with the invention arranged in a well tubing suspended in a well casing;

FIG. 2 shows the safety valve of FIG. 1 in open position;

FIG. 3 shows the safety valve of FIG. 1 in fully closed position; and

FIGS. 4 and 5 illustrate typical flowing pressure gradient curves.

DETAILED DESCRIPTION OF THE INVENTION

There is shown in FIG. 1 a well casing 10 in which a well pipe or tubing string 11 is suspended. A packer 12 closes the annulus between the casing and tubing string. The directional flow of well fluids from a subsurface producing formation is indicated by the arrowed lines. A safety valve 13 is arranged in tubing 11. An adjustable choke 14 is connected to tubing 11 at the surface and a suitable timer control 15 controls the operation of choke 14.

In FIG. 2 details of valve 13 are shown. A valve housing 20 contains a valve seat 21 and an opening 22 in which is positioned a valve 22*a*. The lower end of flow tube 25 contains openings 26 and a valve seating surface 27. In the valve's closed position as seen in FIG. 3 surface 27 has engaged valve seat 21 and openings 26 in the flow tube are positioned within housing 20. Flow tube 25 is provided with an outwardly extending upper shoulder piston 30 and an outwardly extending lower shoulder piston 31. These shoulders together with inner wall of housing 20 form three chambers, 35, 36 and 37, isolated from each other by seals 40 which engage the inner wall of housing 20. Upper seal 41 on the inner wall of housing 20 above chamber 35 and lower seal 41 on the inner wall of housing 20 below chamber 37 are balanced seals. They engage the outer wall of flow tube 25 and prevent fluids from flowing between flow tube 25 and the inner wall of housing 20 at those points. Lower chamber 37 contains a spring 45 which acts against shoulder 31 to urge or bias flow tube 25 upwardly towards the closed position of the valve. Shoulder 31 may be provided with a passage 46 which extends from the inner wall of flow tube 25 to the outer wall thereof between seals 40 located on shoulder 31. The valve 22*a*, arranged in the opening 22, is used to charge chamber 30 with and retain in chamber 30 nitrogen or other gas. Chamber 36 is completely filled with a suitable hydraulic fluid as indicated. The outer wall of flow tube 25 is formed to provide an annular recess 47 a predetermined distance below shoulder piston 30. An annular shoulder 48 is provided on the inner

wall of housing **20.** Shoulder **48** contains a small sized orifice **49** and a large fluid return bypass **50** on one end of which is positioned a flexible check valve flapper **51.** A seal **52** is positioned on the inner wall of shoulder **48** and engages the unrecessed portion of the outer wall of flow tube **25.** An opening **55** in flow tube **25** is covered with sintered metal or other filter and fluidly communicates chamber **35** and the interior of flow tube **25.**

Typical flowing pressure gradient curves are shown in FIGS. **4** and **5.** In FIG. **4** the flowing pressure at an assumed valve depth of 3,000 feet for a gas-oil ratio (GOR) of 600 is 540 psig as indicated at **60.** In FIG. **5** at 3,000 feet and a GOR of 600 the flowing pressure is 1,190 psig as indicated at **61.** Thus, when the producing rate is reduced from 300 barrels per day to 400 barrels per day the surface tubing pressure increases to 400 psig and the pressure at 3,000 feet depth increases to 1,190 psig. A 200 psig pressure change at the surface results in a 650 psi pressure change at 3,000 feet. These flowing pressure gradient curves are for stabilized conditions and do not reflect the time required to achieve the pressure changes.

In operation, referring in particular to FIG. **2** and using the pressure curve examples given above flow tube **25** is biased upwardly by spring **45** and, if used, nitrogen pressure, acting with an upward force on shoulder **31** to bias the valve toward its closed position. The valve is operable by spring force alone however addition of the nitrogen charge increases flexibility. Flow tube **25** is biased downwardly by the force of tubing fluid pressure acting with a downward force on piston shoulder **30** in chamber **35** to bias the valve open. Chamber **35** is in fluid communication with tubing pressure within flow tube **25** through the sintered metal or other filter covered opening **55.** The valve closes when seating surface **27** engages valve seat **21** as shown in FIG. **3.**

During normal flowing conditions the force exerted by for example 540 psig tubing pressure is less than the force acting upwardly on shoulder piston **31** caused by spring **45** alone or together with a gas charge in chamber **37** and the valve is consequently attempting to close by movement of flow tube **25** upwardly as indicated in FIG. **2.** Closure of the valve is slowed or retarded however by the hydraulic fluid in chamber **36** which is forced to pass through the small sized orifice **39** in shoulder **48** while seal **52** engages the outer wall of flow tube **25.** After the flow tube has moved a perdetermined distance towards closure, the recess **47** on the outer wall of flow tube **25** moves into position adjacent seal **52** permitting the hydraulic fluid to bypass the small sized orifice **49** and cause rapid upward movement of flow tube **25** and thereby rapid closure of the valve. However, before recess **47** reaches seal **52** to permit fluid to bypass the small sized orifice **49** the pressure at the safety valve has increased to 1,190 psig tubing pressure through prior operation of the timer **15** and decreasing the size of adjustable choke **14.** The pressure pulse passes through opening **55** into chamber **35** and acts on shoulder piston **30** to force flow tube **25** downwardly to its initial position. In moving the flow tube downwardly hydraulic fluid in chamber **36** bypasses small sized orifice **49** and flows through large fluid return bypass **50** and flapper valve **51** which results in rapid resetting of flow tube **25** and the safety valve. The tubing pressure is cycled continuously to allow continuous production of fluids through flow tube **25** without interruption under normal operations. When it is necessary or desirable to close the safety valve the timer does not operate the adjustable choke to reduce the size thereof and flow tube **25** moves upwardly to engage the valve seating surfaces as shown in FIG. **3.**

Timer **15,** choke **14** and the control apparatus for controlling choke **14** are commercially available components. For example, the choke might suitably be a diaphragm-type valve which is spring-opened and fluid pressure closable. The timer may suitably be an electric or mechanical clock mechanism which energized a solenoid valve at preselected times. The solenoid valve opens at such times to permit a gas pressure to operate the choke to reduce choke size a preselected amount momentarily.

Changes and modifications may be made in the illustrative embodiments of the invention shown and described herein without departing from the scope of the invention as defined in the appended claims.

Having fully described the nature, objects, apparatus, method and advantages of my invention I claim:

1. A subsurface safety valve for use in closing off flow of well fluids through well tubing comprising:

a valve housing;

a flow tube arranged in said valve housing and movable between a first position in which well fluids are prevented from flowing through said flow tube and a second position in which well fluids are permitted to flow through said flow tube;

biasing means for urging said flow tube to its first position;

means for retarding movement of said flow tube from its second towards its first position; and

said flow tube including means permitting the absolute pressure of said well fluids to act on said flow tube to move said flow tube, said flow tube being moved towards its second position against the bias of said biasing means when said absolute pressure exceeds a predetermined amount, said absolute pressure exceeding said predetermined amount periodically during movement of said flow tube towards its first position.

2. A subsurface safety valve as recited in claim **1** in which when said flow tube reaches a third position between said second position and said first position, in its travel from its second towards its first position, said flow tube is returned to its second position.

3. A subsurface safety valve as recited in claim **2** including first, second and third chambers formed between said flow tube and said valve housing, said biasing means being arranged in said first chamber, said means for retarding movement of said flow tube being located in said second chamber and said means permitting the absolute pressure of said well fluids to act on said flow tube including an opening in said flow tube fluidly communicating said well fluid pressure and said third chamber.

4. A subsurface safety valve as recited in claim **3** in which two spaced apart shoulders extend from said flow tube to engage the inner wall of said valve housing to form together with the inner wall of said valve housing said first, second and third chambers, said second chamber containing hydraulic fluid and orifice means for restricting movement of said hydraulic fluid as said flow tube moves from its second to its third position.

5. A subsurface safety valve as recited in claim 4 in which said biasing means includes a spring.

6. A subsurface safety valve as recited in claim 5 in which said biasing means includes a spring and gas under pressure.

7. A subsurface safety valve as recited in claim 6 in which said flow tube includes an additional opening adjacent one end thereof and sealing means also adjacent said one end adapted to seal with said housing, said additional opening being sealed off within said housing by said sealing means engaging said housing to close off flow of well fluids through said flow tube when said flow tube is in its first position, said additional opening fluidly communicating said well fluids and the interior of said flow tube when said flow tube is in positions other than said first position thereof.

8. A subsurface safety valve as recited in claim 7 including means arranged in said second chamber to permit said flow tube to move rapidly towards its first position after it has reached its third position, and means in said second chamber permitting said flow tube to move rapidly towards its second position in response to well fluid pressure.

9. A subsurface safety valve system for use in closing off flow of well fluids through well tubing comprising:

a valve housing;

a flow tube arranged in said valve housing and movable between a first position in which well fluids are prevented from flowing through said flow tube and a second position in which well fluids are permitted to flow through said flow tube;

biasing means for urging said flow tube to its first position;

means for retarding movement of said flow tube from its second towards its first position;

said flow tube including means permitting the absolute pressure of said well fluids to act on said flow tube to move said flow tube, said flow tube being moved towards its second position against the bias of said biasing means when said absolute pressure exceeds a predetermined amount, said absolute pressure exceeding said predetermined amount periodically during movement of said flow tube towards its first position; and

a surface choke arranged in said surface tubing adapted to be periodically closed to reduce the flow of well fluids therethrough and thereby increasing absolute pressure of the well fluids at the subsurface valve.

10. A subsurface safety valve system as recited in claim 9 in which when said flow tube reaches a third position between said second and first positions said flow tube is returned to its second position.

11. A subsurface safety valve system as recited in claim 10 including first, second and third chambers formed between said flow tube and said valve housing, said biasing means being arranged in said first chamber, said means for retarding movement of said flow tube being located in said second chamber, and said means permitting the absolute pressure of said well fluids to act on said flow tube including an opening in said flow tube fluidly communicating said well fluid pressure and said third chamber.

12. A subsurface safety valve system as recited in claim 11 including two spaced apart shoulders extending from the outer wall of said flow tube to the inner wall of said valve housing forming with the inner wall of said valve housing said first, second and third chambers, said second chamber containing hydraulic fluid and orifice means for restricting movement of said flow tube from said second to said third position thereof.

13. A subsurface safety valve system as recited in claim 12 in which said biasing means includes a spring.

14. A subsurface safety valve system as recited in claim 13 in which said biasing means includes a spring and pressurized gas.

15. A subsurface safety valve system as recited in claim 14 in which said flow tube includes an additional opening adjacent one end thereof and sealing means also adjacent said one end adapted to seal with said housing, said additional openings being sealed off within said housing by said sealing means engaging said housing to close off flow of well fluids through said flow tube when said flow tube is in its first position, said additional opening fluidly communicating said well fluids and the interior of said flow tube when said flow tube is in positions other than said first position thereof.

16. A subsurface safety valve system as recited in claim 15 including means arranged in said second chamber to permit said flow tube to move rapidly towards its first position from its third position, and means in said second chamber permitting said flow tube to move rapidly towards its second position in response to well fuid pressure.

17. A subsurface safety valve system as recited in claim 16 including timer means connected to said surface choke for periodically choking said surface choke to increase absolute pressure within said well tubing.

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