Oct. 11, 1966 D. V. CHENOWETH 3,277,831

FLUID DYNAMIC PUMPING SYSTEM AND APPARATUS

Filed Nov. 16, 1964 3 Sheets-Sheet 1

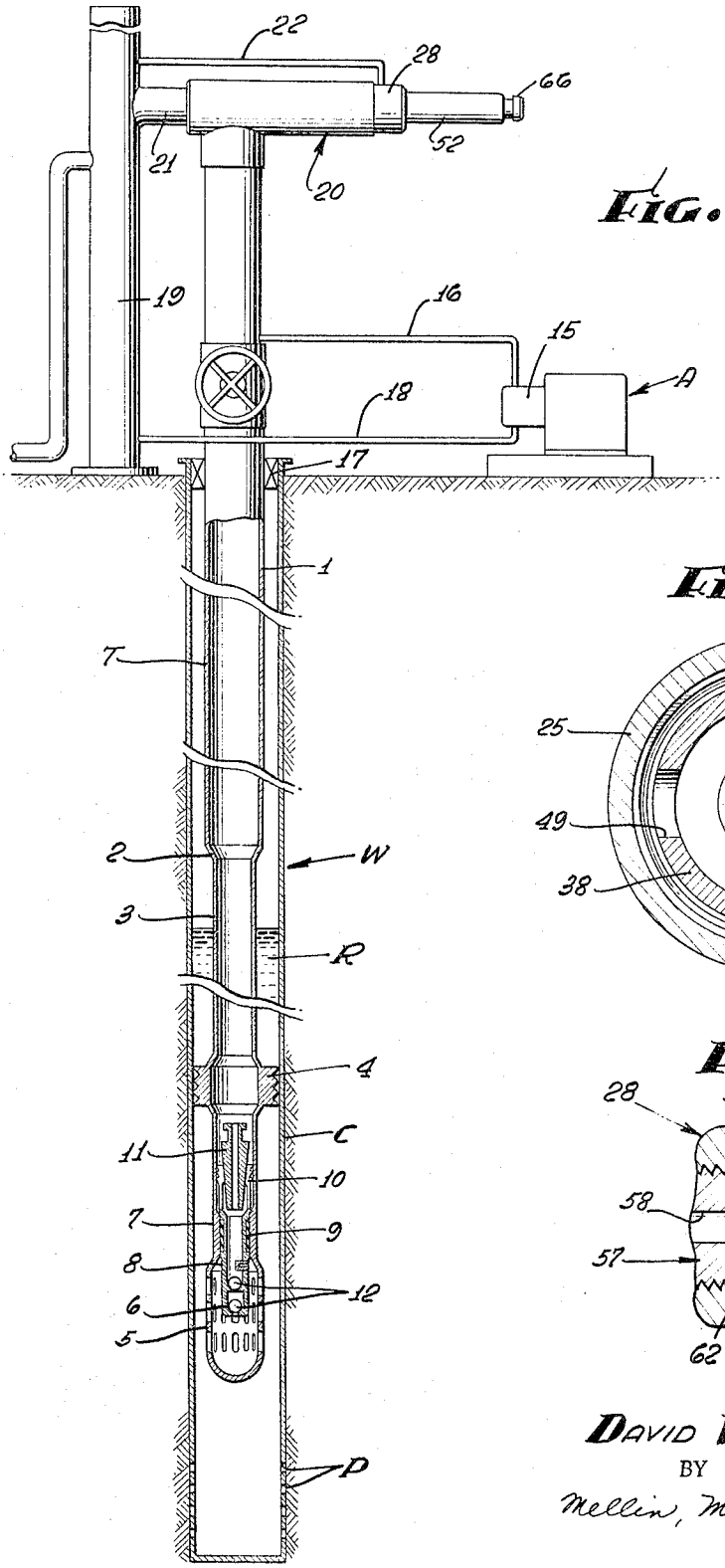


FIG. 1.

FIG. 4.

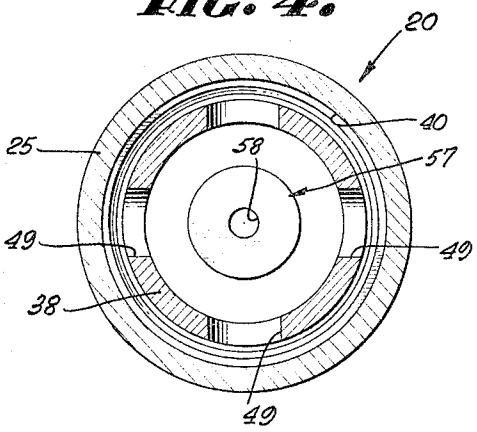
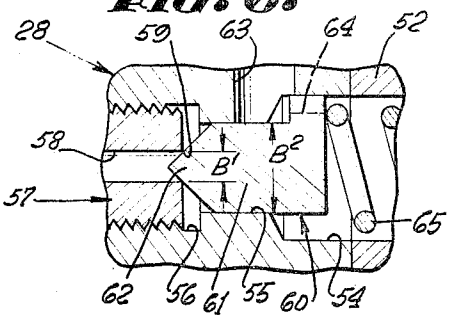


FIG. 6.



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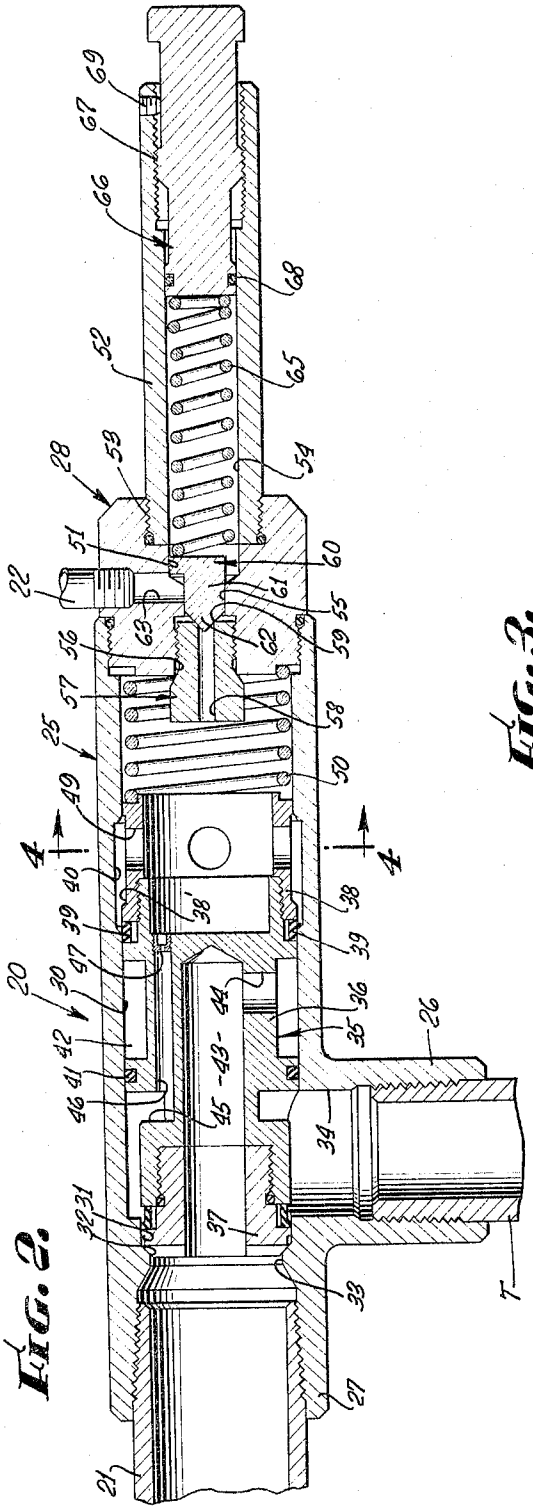


FIG. 2.

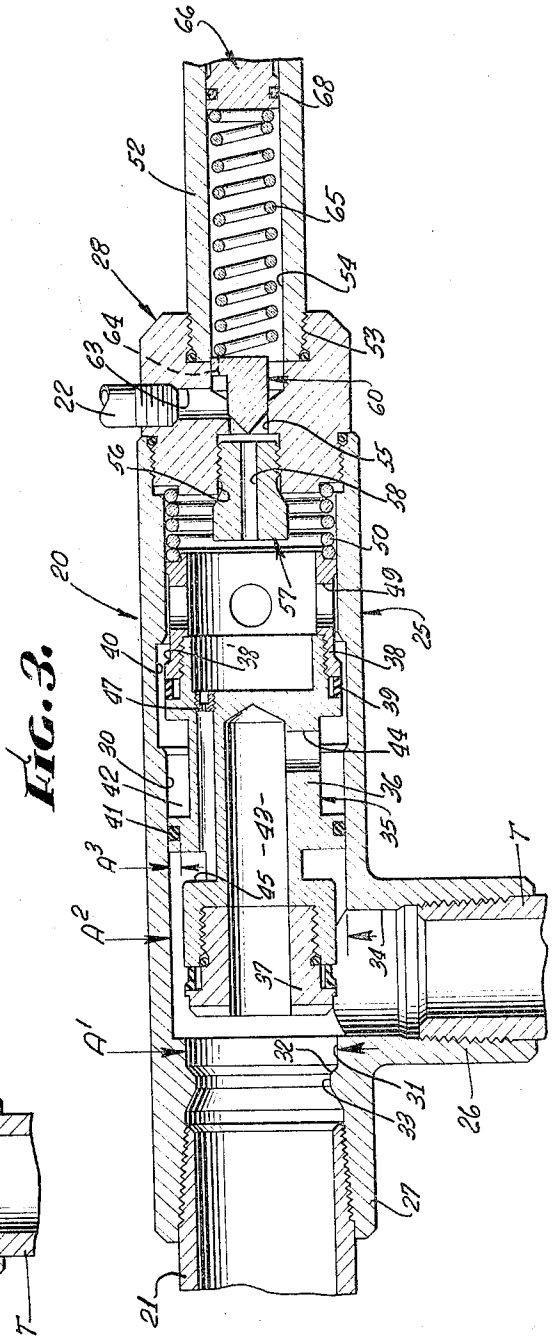


FIG. 3.

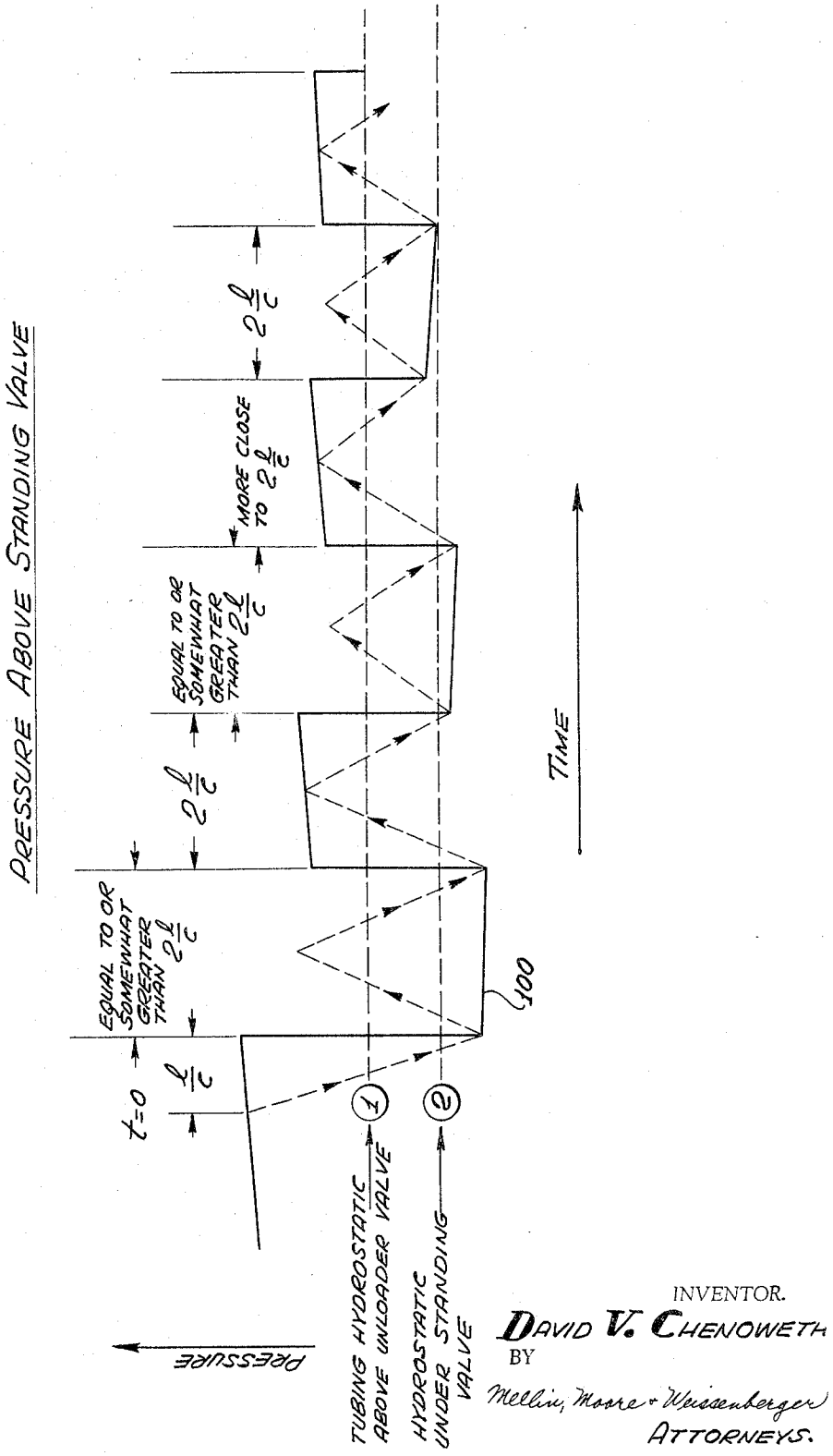
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FLUID DYNAMIC PUMPING SYSTEM AND APPARATUS

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FIG. 5.



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FLUID DYNAMIC PUMPING SYSTEM AND APPARATUS

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Filed Nov. 16, 1964, Ser. No. 411,456
21 Claims. (Cl. 103—46)

The present invention relates to well pumps, and more particularly to a pumping system which involves the use of dynamic forces of the column of fluid to be pumped to effect a pumping action, as well as to means for initiating dynamic forces within the column of well fluid.

In the pumping of wells, it is known to impose on the column intermittent pressure waves, for example, by means of a cyclically operated piston which causes fluid oscillation and a pressure wave in the column which travels to the subsurface standing valve and returns to the surface essentially in a sinusoidal wave oscillating fashion. Such systems critically depend upon ideal adjustment of input frequency relative to production tubing or column length to the standing valve; that is, resonant timing.

The present invention contemplates a more efficient and simple system wherein non-sinusoidal pressure pulses or waves are created, such pulses being essentially "square waves" or waves which have a generally sawtooth pattern.

An object of the invention is to provide a well pumping system wherein pressure is induced in the fluid column at the top of the well and results in a series of pressure pulses at the standing valve below hydrostatic column pressure, the pulses being non-sinusoidal and essentially square pressure waves, whereby flow of well fluid through the standing valve will occur.

Another object is to provide such a system which functions responsive to a condition created in the production string of pipe, rather than in timed cycles. More particularly, this object contemplates creating a super-hydrostatic pressure in the production string which is suddenly released so as to produce a pressure rarefaction wave traveling down the tubing string as fluid in the tubing flows therefrom and the tubing contracts, resulting in a pressure drop at the standing valve and hence resulting in the transfer of fluid from the reservoir through the standing valve into the production column.

Another object is to provide a pressure responsive unloader means for allowing the build-up of pressure within the production pipe and which will release such pressure suddenly when a predetermined elevated pressure is reached so as to initiate the rarefaction wave and the resultant production of fluid according to water hammer principles.

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 view illustrating the system applied to a well production pipe located in a well bore;

FIG. 2 is a vertical sectional view through the unloader device, shown in closed condition;

FIG. 3 is a fragmentary view corresponding to FIG. 2, but showing the unloader device open;

FIG. 4 is a transverse sectional view taken on the line 4—4 of FIG. 2;

FIG. 5 is a diagrammatic view showing the pressure wave form resulting from the use of the invention;

FIG. 6 is an enlarged fragmentary section through a portion of the pilot valve region of the unloader valve.

Referring to FIG. 1, the invention is shown as applied to a well W in which, typical of certain well completions, casing C has been set, the casing having perforations P for the flow of formation fluids from the subsurface earth formation into the well bore within the casing. Other well completions may be employed, but the significant aspect is the provision of a body or reservoir R of well fluid in the well bore, which reservoir is to be recovered by the present pumping system.

Installed in the well bore is a string of production tubing T, herein shown as having an upper tubing section 1 of larger diameter, reduced at 2 to a lower section of tubing 3 of smaller diameter. Adjacent the lower end of tubing 3 is a typical tubing anchor 4 and beneath the anchor is a slotted production tube 5 through which reservoir fluid may pass into the tubing T. A typical standing valve 6 is provided, preferably in the form of a wire line retrievable valve assembly adapted to be seated in a landing nipple 7. The standing valve 6 is thus shown as having a body 8 adapted at 9 to sealingly engage in the nipple. The body 8 is anchored in the nipple by latch members 10 operable by a recovery head 11 engageable by a wire line operated recovery tool (not shown). In the valve 6 are preferably a pair of upwardly opening ball valves 12 which will open to pass reservoir fluid into the tubing T when tubing pressure is less than reservoir pressure. Wells that flow constantly or in heads have or periodically attain reservoir pressure in excess of tubing hydrostatic head and therefore may not require pumping.

The present invention is addressed to the problem of producing those wells which require pumping, and means are provided whereby the tubing hydrostatic pressure is intermittently reduced below reservoir pressure as a consequence of over-pressuring the tubing and then suddenly unloading the tubing to allow fluid expansion and tubing contraction to cause flow from the tubing as a pressure rarefaction wave moves down the tubing to the standing valve, resulting in a pressure reduction below reservoir pressure until the kinetic energy of the upwardly travelling tubing fluid is dissipated and a secondary downward moving compression wave is produced.

The surface apparatus for accomplishing the pressurizing of the tubing fluid is shown as including a motor-pump assembly A, the pump 15 of which has an outlet conduit 16 leading to the tubing T above a conventional well head assembly generally denoted at 17. The return line 18 to the pump 15 leads from a tank 19 disposed at a convenient location and to be later described. The pump 15 is of a type which will displace a steady flow through conduit 16 without surges and is, therefore, preferably a centrifugal or rotary pump rather than a positive displacement plunger pump.

The apparatus for effecting a sudden release of tubing pressure is shown as including a valve assembly 20 mounted at the top of and in communication with the tubing T. An outlet conduit 21 leads from the valve 20 to the tank 19 and a conduit 22 leads from the top of tank 19 to the valve for a purpose which will hereinafter be described.

Referring to FIG. 2, wherein the valve assembly 20 is shown in detail, it will be noted that it comprises a tubular body 25 having an inlet coupling member 26 for connection to the upper end of tubing T and an outlet coupling member 27 for connection to the outlet conduit 21 described above and which leads to the tank 19. At the end of the body 25 remote from the outlet coupling member 27 is a pilot valve fitting 28 connected to the conduit 22 described above which also leads to tank 19.

Interiorly of the valve assembly **20**, the body **25** has a bore **30** leading inwardly from the fitting **28** to a reduced bore **31** adjacent to the outlet coupling member **27**, this reduced bore ending at a valve seat **32** which circumscribes an outlet port **33**. Leading from the inlet coupling member **26** into the bore **30** at a right angle is an inlet bore or port **34**.

Reciprocable in the bore **30** is a valve member **35** including a central body section **36**. The central section **36** has as at one end a head **37** adapted to fit within the reduced bore **31** and sealingly engage the seat **32**. At its other end the central section **36** has a sleeve **38** threaded thereon and forming with the section **36** a seal ring chamber for a seal ring **39**. Between its ends the sleeve is of reduced diameter at **38'** and the body **25** has an opposing enlarged bore **40**. The central section **36** also has a peripheral seal **41** slidable in the body bore **30** and an annular groove or channel **42** extending thereabout between seals **39** and **41**.

Extending endwise through the head **37** of the valve member **35** is a passage **43**, and a port **44** establishes communication between the passage **43** and the channel **42**. Adjacent the juncture of the head **37** with the central body section **36** the latter has a groove or channel **45**, and a passageway **46** establishes communication between the groove **45** and the opposite end of the body section **36**. In this passageway **46** is a flow restrictor or orifice **47** which will impede the flow of fluid through the passageway **46** into the bore **30** at the end of the bore **30** in which sleeve **38** is disposed. The flow restrictor **47** opens into the sleeve **38** which has radial ports **49** leading to the groove **40** on the outside of the sleeve **38**.

It will now be understood that the valve member **35**, comprising section **36**, head **37** and sleeve **38**, is a piston valve member slidable in the bore **30** responsive to fluid pressures acting thereon, so as to be disposed in a first or closed position preventing flow of fluids from the inlet to the outlet (FIG. 2), or in a second or open position at which fluid may flow through the inlet to the outlet, as shown in FIG. 3.

Spring means are shown for normally biasing the valve member toward said first or closed position in the form of a helical compression spring **50** acting at one end on the member **35** and at the other end on the pilot valve fitting **28**.

The pilot valve fitting has a bore **51** aligned with the bore **30** in body **25** and an extension **52** formed as part of the fitting or comprising a tubular member threaded thereto as at **53**, provides an extension **54** of the bore **51**. Inwardly of the bore **51** is a reduced bore **55** which leads to another bore **56** in which is threadedly or otherwise disposed a pilot valve seat element **57** having a small passage **58** circumscribed by a seat **59**.

Slidable in the bores **51** and **55** of the fitting **28** is a pilot valve element **60** having a small diameter section **61** slidable in bore **55** and having a conical nose **62** engageable with the seat **59**. The fitting **28** has a port **63** in communication with conduit **22** leading to tank **19**, and this port **63** intersects with both bores **51** and **55**, the pilot valve element **60** being formed with a passage or slot **64** so that the extension bore **54** of extension **52** communicates with the port **63**.

Pilot valve element **60** is biased toward the seat **59** by a spring **65** in the bore **54**, one end of the spring engaging valve element **60** and the other end engaging a force adjustor **66** slidable in the bore **54** and axially adjustable to different fixed positions by a threaded connection **67** with the extension **66**. The adjustor **66** is sealed at **68** in the extension and is adapted to be fixed in adjusted position by means of a set screw **69** or by other suitable means.

The function of the valve is such that it will remain closed so long as pressure in tubing T acting on the valve member **35** and on the pilot valve element **60** does not overcome the counterforce acting to hold the pilot valve closed. Once open, the valve member **35** will remain in the open position so long as flow continues through the inlet to the outlet.

More particularly, it will be noted upon reference to FIG. 2 that with the valve head **37** seated (valve closed) and the pilot valve closed, tubing pressure P^1 finds access to the bore **30** between valve member **35** and the pilot valve fitting **38**, through passageway **46** from groove **45**, and, therefore, there is a force in a direction urging the valve member **35** to stay on its seat which is $(P^1-P^2)A^1$, where A^1 is the cross-sectional area of member **35** where the head sealingly fits the bore **31** in the coupling member **27**, and P^2 is the pressure in the outlet **21**, which will also be the pressure in the conduit **22**. In addition, the spring **50** provides a force in the same direction. In the discussion given below, A^2 is the area of the bore **30**, and A^3 is the annular area between the bores **30** and **31**.

Opposed to this is a force in a direction urging the valve head **37** off its seat **31**, which is $P^2 \times A^1$, it being noted that the pressure in the channel **42** is balanced out when the valve is closed. However, with the valve closed, the pressure P^2 is substantially zero, or is comparatively small, so that the valve remains closed.

The purpose of the pilot valve is to reduce P^1 on the pilot side of the valve member **35**. Hence, when the tubing pressure P^1 is increased to a given value by running of the pump **15**, the effect of pressure P^1 on the cross-sectional area B^1 of the pilot valve member **60** at the seat **59** will be to overcome the effect of pressure P^2 in the tank **19** on the cross-sectional area B^2 of the pilot valve member **60** plus the force of the spring **65** tending to hold the pilot valve closed, and the pilot valve will be opened, venting the pressure P^1 in the valve body **35** to the tank **19** on the pilot side of the valve member **35**.

The opening of the pilot valve will be quick, since the member **60** has, as just mentioned, the area B^1 subjected to pressure P^1 when closed, but as the member **60** is cracked off its seat the entire area B^2 of the portion **61** of the pilot valve will be exposed to pressure P^1, thereby providing a sudden larger order force tending to open the pilot valve.

The opening of the pilot valve **61** reduces the pressure acting on the valve member **35** on the downstream side of the orifice **47** and tending to hold the valve member in its closed condition or to the left in FIG. 2. However, the pressure P^1 continues to act over the annular area A^3 of the valve member **35** between the seal diameter of the head **37** and the seal **41**, moving the valve **35** to the right a short distance to shift the seal **39** into the enlarged bore **40** which suddenly greatly reduces the pressure in the body **25** at the right of the valve member to the tank pressure P^2, since there is then communication between the outlet conduit **21** and the portion of the body **25** containing the spring through the passage **43**, part **44**, groove **42**, groove **40**, and ports **49**. Since the pressure P^1 greatly exceeds the pressure P^2, the inlet pressure acting over the area A^3 suddenly shifts the valve member **35** to its fully opened position, as shown in FIG. 3.

Upon reference to FIG. 3, it will be noted that when the valve member **36** is in the second or open position, the pressure of fluid at the outlet passes from the groove **42** into the groove **40** in the body **35**; that is, around the seal **41**, and through the groove **38'** into the ports **49**. Under these circumstances, the conditions are such that the valve will remain open so long as fluid flows through the valve and the pressure at the outlet acting on the adjacent end of the valve member **35** exceeds the pressure acting oppositely at the opposite end of the member **35** combined with the force of spring **50**.

The purpose of the tank **19** is to enable discharge of fluid into a gaseous medium from the valve outlet **21** and to vent the pilot valve to such gaseous medium. When the valve **20** is located adjacent to a storage facility into which the valve may discharge produced well fluids to atmosphere, the tank **19** is not necessary. Otherwise, the tank should be employed with a flow line F leading to a

storage or transfer facility from a location in the tank 19 below the elevation at which the valve discharges into the tank.

In the practical application of the invention the system functions as follows:

With the valve member 35 in the closed position, as shown in FIG. 2, and the tubing T filled with oil, for example, running of the pump 15 will cause a build up of pressure within the tubing T against the downwardly closing standing valve 6, causing elastic expansion of the tubing and compression of the well fluid column within the tubing.

Referring to FIG. 5, the resultant pressure wave and velocity is diagrammatically illustrated in relation to hydrostatic pressure in the tubing above the unloader valve 20 (base line 1) and hydrostatic pressure below the standing valve (base line 2); and where l=the length of the tubing to the standing valve, c is the speed of sound through the liquid, and t=time, the solid line designating pressure at given stages. It is to be noted that the wave is not sinusoidal, a substantially squared or saw toothed wave being produced, resulting in periods of production of rservoir fluid through the standing valve when the tubing pressure is reduced below normal hydrostatic pressure during the time that the pressure front moves from the lower limit to the higher limit and returns to the lower limit.

More specifically, a pressure greater than tubing hydrostatic pressure is built up across the standing valve until the pressure is of such magnitude as to cause sharp, sudden opening of the unloader valve 20, at time t=0. At this time, release of the pressure to normal hydrostatic pressure releases the stored energy in the compressed fluid and elastically stretched tubing, discharging a stored volume through the valve 20. The resultant upward kinetic energy wave front (broken arrows in FIG. 5) progresses downwardly at sonic velocity, with the fluid above the downward moving front moving upwardly. The front will reach the standing valve in the time l/c, when the column will be at normal hydrostatic pressure and will be moving upwardly; thus causing a rarefaction of pressure 100 and density above the standing valve to a value below the pressure at the standing valve, and the latter will open to admit fluid into the tubing from the reservoir.

The wave front is reflected to the surface at sonic velocity with fluid entering through the standing valve 6 travelling toward the surface behind the now upwardly moving wave front. At the top, the front is again reversed and moves with sonic velocity downwardly to the standing valve to close the same at $3l/c$, while fluid pressure has been reduced at the surface to normal, and creating a downward kinetic energy to effect subsequent elevation of the hydrostatic pressure in the tubing with attendant storing of energy in the fluid and pipe string to continue the fluctuations of pressure and wave front of progressively decreasing amplitude due to dampening effects of friction, until the disturbance is nullified. When the tubing pressure at the dump valve 20 decreases sufficiently, the valve recloses, the pump 15 again proceeding to build up pressure in the tubing string T to a value that will again cause a sudden opening of the valve 25 to again cause flow of fluid into the tubing string.

During portions of each cycle, stored energy is converted to kinetic energy or fluid velocity, resulting in pressure reductions below the hydrostatic pressure gradient or vapor pressure of the fluid along the column, thus allowing gas to break out of the liquid and enhancing performance. As distinguished from this, gas ordinarily breaks out of flowing wells only at or near the surface.

The anchor 4 previously described is preferably employed to minimize tubing and casing wear, which would occur if the tubing were allowed to stretch longitudinally during the pressure fluctuations.

Furthermore, as a means of reducing the magnitude of applied pressure supplied by pump 15 required, the tubing 1 as described above, is larger than the tubing 2, since the reflected rarefaction wave at the standing valve will cause a pressure reduction at the standing valve by an amount greater than the applied pressure if the area of tubing 1 is greater than the area of tubing 2.

I claim:

1. A well pumping system comprising: a string of production pipe adapted to be disposed in a well bore having a reservoir of well fluid, normally closed valve means for admitting reservoir fluid into said production pipe when the pressure in said pipe is reduced below the pressure of said reservoir fluid, means for pressurizing the fluid in said production pipe, and unloader means responsive to the pressure of fluid in said production pipe for abruptly relieving the pressure in said production pipe.

2. A well pumping system comprising: a string of production pipe adapted to be disposed in a well bore having a reservoir of well fluid, normally closed valve means for admitting reservoir fluid into said production pipe when the pressure in said pipe is reduced below the pressure of said reservoir fluid, means for pressurizing the fluid in said production pipe, and pressure responsive means responsive to the pressure of fluid in said production pipe for initiating a substantially square wave rarefaction front at the top of said production pipe for causing said valve means to open and admit reservoir fluid during the period that said front travels from said valve means to said pressure responsive means and back to said valve means.

3. A well pumping system comprising: a string of production pipe adapted to be disposed in a well bore having a reservoir of well fluid, normally closed valve means for admitting reservoir fluid into said production pipe when the pressure in said pipe is reduced below the pressure of said reservoir fluid, means for pressurizing the fluid in said production pipe, and pressure responsive means for initiating a substantially square wave rarefaction front at the top of said production pipe for causing said valve means to open and admit reservoir fluid during the period that said front travels from said valve means to said pressure responsive means and back to said valve means, said production pipe comprising an upper section and a lower section of lesser cross-sectional area than said upper section.

4. A well pumping system comprising: a string of production pipe adapted to be disposed in a well bore having a reservoir of well fluid, normally closed valve means for admitting reservoir fluid into said production pipe when the pressure in said pipe is reduced below the pressure of said reservoir fluid, means for pressurizing the fluid in said production pipe, pressure responsive means for initiating a substantially square wave rarefaction front at the top of said production pipe for causing said valve means to open and admit reservoir fluid during the period that said front travels from said valve means to said pressure responsive means and back to said valve means, tank means at the upper end of said production pipe, said pressure responsive means including a conduit leading to said tank, and said tank having a production fluid outlet from said tank beneath said conduit.

5. A well pumping system comprising: a string of production pipe adapted to be disposed in a well bore having a reservoir of well fluid, normally closed valve means for admitting reservoir fluid into said production pipe when the pressure in said pipe is reduced below the pressure of said reservoir fluid, means for pressurizing the fluid in said production pipe, and pressure responsive means responsive to the pressure of fluid in said production pipe for initiating a substantially square wave rarefaction front at the top of said production pipe for causing said valve means to open and admit reservoir fluid during the period that said front travels from said valve means to said pressure responsive means and back to said valve means, said valve means comprising a pair of check valves spaced axially in said production pipe.

6. A well pumping system comprising: a string of production pipe adapted to be disposed in a well bore having a reservoir of well fluid, normally closed valve means for admitting reservoir fluid into said production pipe when the pressure in said pipe is reduced below the pressure of said reservoir fluid, non-surging pump means for pressurizing said production pipe, and normally closed valve means responsive to a predetermined rise in pressure in said production pipe for abruptly relieving the pressure in said production pipe.

7. A well pumping system comprising: a string of production pipe adapted to be disposed in a well bore having a reservoir of well fluid, normally closed valve means for admitting reservoir fluid into said production pipe when the pressure in said pipe is reduced below the pressure of said reservoir fluid, means for pressurizing fluid in said production pipe, and unloader means for abruptly relieving the pressure in said production pipe, wherein said unloader means includes a valve movable between a first position closing said production pipe and a second open position, said valve having fluid pressure responsive surfaces exposed to pressure in said production pipe for holding the valve in said first position and for moving said valve to said second position upon venting of said production pipe, and means for abruptly venting said production pipe to reduce the pressure acting on said surfaces to hold said valve in said first position.

8. A well pumping system comprising: a string of production pipe adapted to be disposed in a well bore having a reservoir of well fluid, normally closed valve means for admitting reservoir fluid into said production pipe when the pressure in said pipe is reduced below the pressure of said reservoir fluid, means for pressurizing the fluid in said production pipe, and unloader means for abruptly relieving the pressure in said production pipe, wherein said unloader means includes a valve movable between a first position closing said production pipe and a second open position, said valve having fluid pressure responsive surfaces exposed to pressure in said production pipe for holding the valve in said first position and for moving said valve to said second position upon venting of said production pipe, and pilot valve means for abruptly venting said production pipe to reduce the pressure acting on said surfaces to hold said valve in said first position.

9. A well pumping system comprising: a string of production pipe adapted to be disposed in a well bore having a reservoir of well fluid, normally closed valve means for admitting reservoir fluid into said production pipe when the pressure in said pipe is reduced below the pressure of said reservoir fluid, means for pressurizing the fluid in said production pipe, and unloader means for abruptly relieving the pressure in said production pipe, wherein said unloader means includes a valve movable between a first position closing said production pipe and a second open position, said valve having fluid pressure responsive surfaces exposed to pressure in said production pipe for holding the valve in said first position and for moving said valve to said second position upon venting of said production pipe, and pilot valve means for abruptly venting said production pipe to reduce the pressure acting on said surfaces to hold said valve in said first position, said pilot valve means including a member having a small area exposed to fluid pressure in said conduit when said pilot valve means is closed and a larger area exposed to said pressure for abruptly opening said pilot valve means following initial opening thereof responsive to increase in said fluid pressure.

10. A well pumping system comprising: a string of production pipe adapted to be disposed in a well bore having a reservoir of well fluid, normally closed valve means for admitting reservoir fluid into said production pipe when the pressure in said pipe is reduced below the pressure of said reservoir fluid, means for pressurizing the fluid in said production pipe, unloader means responsive to the pressure of fluid in said production pipe for abruptly relieving the pressure in said production pipe upon a predetermined rise in the pressure in said production pipe and means for adjusting said unloader means for response to a selected pressure rise.

11. A well pumping system comprising: a string of production pipe adapted to be disposed in a well bore having a reservoir of well fluid, normally closed valve means for admitting reservoir fluid into said production pipe when the pressure in said pipe is reduced below the pressure of said reservoir fluid, means for pressurizing the fluid in said production pipe, unloader means for abruptly relieving the pressure in said production pipe upon a predetermined rise in the pressure in said production pipe, and means for adjusting said unloader means for response to a selected pressure rise, wherein said unloader means comprises a main valve normally closing said production pipe, and pilot valve means responsive to pressure in said production pipe for controlling opening of said main valve.

12. A well pumping system as defined in claim 11, wherein said pilot valve means includes a first small area subjected to pressure in said production pipe for initiating opening of said pilot valve means and a second large area subjected to pressure following initial opening of said pilot valve for effecting rapid opening of said pilot valve.

13. A well pumping system comprising: a string of production pipe adapted to be disposed in a well bore having a reservoir of well fluid, an upwardly opening standing valve in said production pipe and submerged in said reservoir, unloader valve means at the top of said production pipe, said unloader valve having fluid pressure responsive areas subjected to the pressure of fluid in said production pipe for holding said valve closed, a pilot valve having means for exposing certain of said areas to reduced pressure upon a predetermined increase in the pressure in said production pipe, means for subjecting said pilot valve and the fluid in said production pipe to said predetermined increase in pressure, and said unloader valve also having areas subjected to said increased pressure to open said unloader when said pilot valve is opened, whereby a fluid in said production pipe is free to flow past said unloader valve, and a rarefaction front is caused to travel down said production pipe to cause upward opening of said standing valve to allow fluid from said reservoir to flow into said production pipe.

14. An unloader valve comprising: a valve body having a bore, an inlet leading to said bore, an outlet leading from said bore, a valve member reciprocable in said bore, a valve seat circumscribing said outlet, a head on said valve member engageable with said seat, said valve member having a larger surface subjected to the pressure at said inlet for holding said valve member on said seat and a smaller surface subjected to the pressure at said inlet for moving said valve member off of said seat when the pressure on said larger surface is reduced, pilot means having a valve member subjected to the pressure in said inlet, means for holding said pilot valve means closed when the pressure in said inlet is below a predetermined value and allowing said pilot valve means to open when said pressure in said inlet exceeds a predetermined value, and means for venting said pressure in said inlet to a reduced pressure through said pilot valve means when the latter is open.

15. An unloader valve comprising: a valve body having a bore, an inlet leading to said bore, an outlet leading from said bore, a valve member reciprocable in said bore, a valve seat circumscribing said outlet, a head on said valve member engageable with said seat, said valve member having a passage leading from said bore at said inlet to said bore at the other side of said valve member from said head, said valve member having a first surface at said other side subjected to said pressure for holding said member in a first position with said head engaged with said seat, means effecting a seal between said valve member and said bore intermediate said head and said first

surface, fluid pressure responsive pilot valve means subjected to pressure in said bore at said other end of said valve member for holding said pressure in said bore and relieving said pressure upon a predetermined rise in said pressure, said valve member having a second surface subjected to fluid pressure at said inlet for forcing said valve member to a second position with said head off said seat upon relief of said pressure by said pilot valve means, and passage means for admitting pressure through said head into said bore between said first surface and said pilot valve means when said head is off said seat.

16. An unloader as defined in claim 15, wherein said pilot valve means includes a member having a first pressure responsive surface for initiating opening of said pilot valve means to relieve said pressure and a second larger surface subjected to said pressure upon initiation of opening of said pilot valve means for abruptly fully opening said pilot valve means.

17. An unloader valve as defined in claim 15, wherein said pilot valve means includes a member having a passage for venting said bore, a seat circumscribing said passage, a valve having an end engageable with said seat, a bore in said member in which said valve is reciprocable, said latter bore being larger than the opening through said seat, and said bore communicating with said passage upon initial movement of said valve off said seat.

18. An unloader valve as defined in claim 15, wherein said pilot valve means includes a member having a first pressure responsive surface for initiating opening of said pilot valve means to relieve said pressure and a second larger surface subjected to said pressure upon initiation of opening of said pilot valve means for abruptly fully opening said pilot valve means, and adjuster means engaged with said member for varying the pressure response to said pressure responsive surfaces.

19. An unloader valve comprising: a valve body having a bore, an inlet leading to said bore, an outlet leading from said bore, a valve member reciprocable in said bore, a valve seat circumscribing said outlet, a head on said valve member engageable with said seat, said valve member having a passage leading from said bore at said inlet to said bore at the other side of said valve member from said head, said passage having a flow restrictor therein, said valve member having a first surface at said other side subjected to said pressure for holding said member in a first position with said head engaged with said seat, means effecting a seal between said valve member and said bore intermediate said head and said first surface, fluid pressure responsive pilot valve means subjected to pressure in said bore at said other end of said valve member for holding said pressure in said bore and relieving said pressure upon a predetermined rise in said pressure, said valve member having a second surface subjected to fluid pressure at said inlet for forcing said valve member to a second position with said head off said seat upon relief of said pressure by said pilot valve means, and passage means for admitting pressure through said head into said bore between said first surface and said pilot valve means when said head is off said seat.

20. An unloader valve comprising: a valve body having a bore, an inlet leading to said bore, an outlet leading from said bore, a valve member reciprocable in said bore, a valve seat circumscribing said outlet, a head on said valve member engageable with said seat, a pair of seal means between said valve member and said bore, a groove in said valve member disposed between said seal means when said head is engaged with said seat, a groove in said body axially spaced from said pair of seal means and communicable with said groove in said valve member when the latter is off its seat, a passage leading through said head into the groove in said valve member, a second passage leading through said valve member from a location spaced from said head past said pair of seal means to said bore at the other end of said valve member from said head, and pressure responsive pilot valve means in said bore at said other end of said valve member having means responsive to pressure supplied to said bore between said pilot valve means and said other end of said valve member for venting said bore.

21. An unloader valve comprising: a valve body having a bore, an inlet leading to said bore, an outlet leading from said bore, a valve member reciprocable in said bore, a valve seat circumscribing said outlet, a head on said valve member engageable with said seat, a pair of seal means between said valve member and said bore, a groove in said valve member disposed between said seal means when said head is engaged with said seat, a groove in said body axially spaced from said pair of seal means and communicable with said groove in said valve member when the latter is off its seat, a passage leading through said head into the groove in said valve member, a second passage leading through said valve member from a location spaced from said head past said pair of seal means to said bore at the other end of said valve member from said head, pressure responsive pilot valve means in said bore at said other end of said valve member having means responsive to pressure supplied to said bore between said pilot valve means and said other end of said valve member for venting said bore, and a flow restrictor in said second passage.

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