

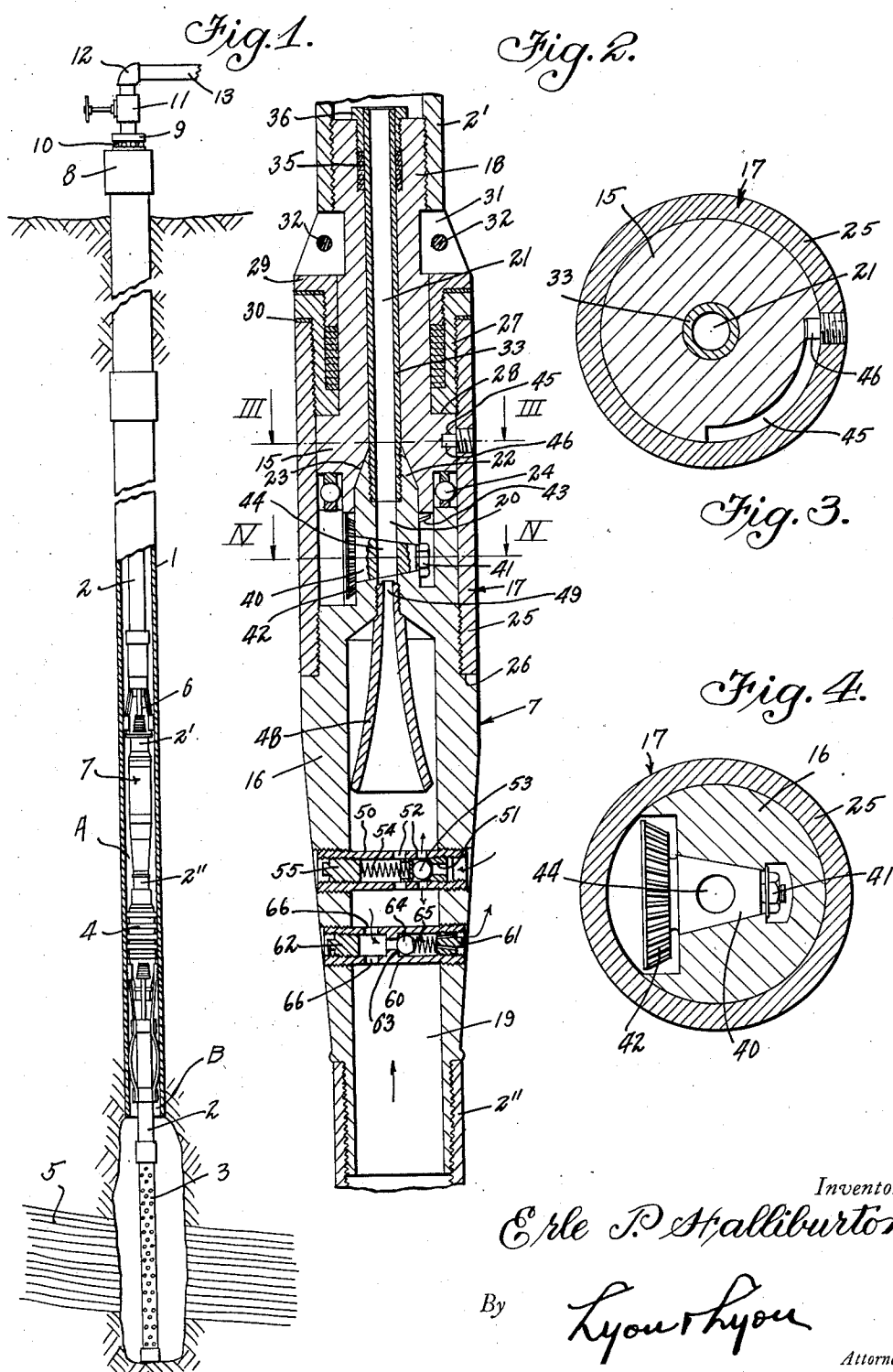
Feb. 26, 1935.

E. P. HALLIBURTON

1,992,424

METHOD OF REGULATING FLOW FROM WELLS AND APPARATUS THEREFOR

Filed July 18, 1932



Inventor
E. P. Halliburton

By
Lyons & Lyon

Attorneys

UNITED STATES PATENT OFFICE

1,992,424

METHOD OF REGULATING FLOW FROM
WELLS AND APPARATUS THEREFOR

Erle P. Halliburton, Los Angeles, Calif.

Application July 18, 1932, Serial No. 623,164

8 Claims. (Cl. 166—2)

This invention relates to a method of regulating the flow of wells and particularly the flow of liquids from wells, whereby numerous advantages and results may be attained. The method of this invention is particularly applicable to the regulation of oil wells where the oil is under a pressure attributable to gas in the oil-bearing formation and in the well hole. The method is applicable, however, wherever the liquid in the formation is under a gas pressure and is of particular advantage wherever the gas, or a portion thereof, is in actual solution in the liquid which it is desired to withdraw from the well hole.

In order to facilitate the understanding of this invention, however, the subsequent detailed description of the method of operation and of a device suitable for use therein, will relate to its adaptation to oil well operations.

In flowing wells, the liquid is caused to flow to the surface because of rock pressure, this rock pressure being generally evidenced as a gas pressure within the formation and within the well hole. The oil discharged through the tubing is very often mixed with gas. In addition to free gas, a considerable added proportion of gas exists in solution in the oil. A gradual release of pressure does not cause this dissolved gas to be rapidly removed from solution in the oil. When the oil is permitted to stand in storage tanks for an appreciable length of time, however, the gaseous constituents originally in solution in the oil separate therefrom and pass off, carrying with them a certain proportion of the lighter hydrocarbon constituents present in the oil. This storage step is generally referred to as "weathering" and some of the most highly desirable low boiling point hydrocarbons are lost. In normal operation, therefore, this dissolved gas or gaseous constituents dissolved in the oil perform no useful function as they do not assist in raising the oil to the surface, but instead necessitate a gas separation step on the surface, in which gas separation step they cause losses of valuable hydrocarbon constituents.

Moreover, it will be obvious that the removal of gas from a well shortens the life of the well in that a certain gas or rock pressure is necessary to cause the well to flow and the more gases withdrawn, the more quickly the gas or rock pressure in the well hole and in the formation will drop. Actually, it has been found that the freezing or evolution of gas in the formation itself is preferably to be retarded or prevented as much as possible as the evolution of gas in

the formation protects the formation and prevents the withdrawal of all of the oil.

Flowing wells are normally controlled and regulated by adjusting a valve positioned in the string of tubing at the top of the well. When it is desired to shut a well down, this valve is closed, leaving a column of oil in the tubing. As a result, when it is desired to start the well flowing again, a valve at the top of the tubing is opened. The gas pressure in the well hole must be sufficient to overcome the static head of this column of oil. For this reason, even though a gas pressure of say 100 pounds, exists in the formation, and a flowing well will continue to operate under such pressure, the same well when closed and then reopened will not flow as the 100 pounds is insufficient to overcome the static head of the column of oil remaining in the tubing. Under such conditions, it is necessary to swab or bail out the oil from the tubing before the well will start flowing again.

The method of this invention distinguishes from the prior art and practices in a number of ways. In the first place, the flow of the well is regulated not by means of a valve positioned in the upper end of the tubing on the surface, but instead by means of a valve positioned near the bottom of the well hole so that when the well is shut in, a residual column of oil in the tubing is not formed. Furthermore, by the method of this invention the flow of the well is not dependent upon the quantity of free gas and the pressure of the free gas existing in the bottom of the well hole or in the formation, but instead the gas in solution in the oil is liberated and evolved from the oil at a point near the bottom of the well hole and this gas then utilized in forcing the oil to the surface. Furthermore, the dynamic velocity of the gas thus evolved from solution in the oil, is effectively employed in causing the well to flow. As a result of the method of operation of this invention, the oil reaching the surface is substantially free from dissolved gas and weathering losses are thereby eliminated. Moreover, a relatively small quantity of gas from a source heretofore not employed (the gas in solution in the oil) is caused to perform the useful function of raising the oil to the surface.

The method of this invention, furthermore, contemplates the establishment of balanced pressures within the well hole. The invention, for example, contemplates the formation of a zone in the well hole between the tubing and the casing, wherein pressure may be caused to accumulate until it is substantially equal to the pressure ex-

isting within the formation from which the oil is being withdrawn. Thereafter such pressure is permitted to enter the lower zone in direct communication with the formation whenever the pressure in such lower zone decreases to a predetermined point below the pressure existing in the upper zone.

The invention not only relates to a method of controlling and regulating the flow of wells, but in addition relates to a flowing device whereby the method may be effectively carried out.

An object of this invention is to disclose and provide a method of regulating the flow of liquids from wells whereby gaseous constituents ordinarily in solution in the liquid are evolved and utilized in forcing the liquid to the surface.

Another object of the invention is to disclose and provide a method of regulating the flow of oil from wells, whereby gas held in solution in the oil is liberated and evolved therefrom, at near the bottom of a well hole, its velocity rapidly increased and the dynamic velocity of said gas utilized in causing the well to flow.

A further object of this invention is to disclose and provide a method of regulating the flow of wells by manipulating pressure relationships at near the bottom of a well hole and using pressure accumulations to facilitate the flow of oil.

An object of the invention is to disclose and provide a device for controlling the flow of oil and gas from wells.

Another object of the invention is to disclose and provide a device regulatable from the ground surface, whereby gas in solution in the oil may be evolved therefrom at near the bottom of the well hole.

A further object of the invention is to disclose and provide a combination of elements whereby gas pressures and gas in solution in an oil may be most effectively utilized in causing an oil well to flow.

These and other objects, uses and advantages of the invention will become apparent to those skilled in the art from a contemplation of the invention as described hereinafter.

In describing the invention, reference will be had to the appended drawing, in which

Fig. 1 diagrammatically illustrates an arrangement of elements within a well hole whereby the method of this invention may be put into practice.

Fig. 2 is an enlarged longitudinal section through one form of valve device made in accordance with this invention, for use in the arrangement shown in Fig. 1.

Figs. 3 and 4 are transverse sections taken along the planes 3—3 and 4—4 indicated in Fig. 2.

As shown in Fig. 1, the casing 1 extends downwardly into the well hole and positioned therein is a tubing 2 provided at its lower end with a section of perforated or slotted pipe 3. Near the bottom of the string of tubing 2 there is carried a suitable packer 4 capable of forming a substantial barrier between the casing 1 and the tubing 2, thereby forming an upper zone indicated at A between the casing 1 and the tubing 2, and a lower zone indicated at B and in direct communication with the bottom of the well hole which is being supplied with oil from the formation 5.

The tubing 2 may also be provided with a suitable blow-out preventer indicated generally at 6. This blow-out preventer 6 is provided with a plurality of slips capable of engaging the side of the casing 1 and preventing upward motion of the tubing therein. Between the blow-out preventer 6 and the packer or barrier 4 is a valve structure,

indicated generally at 7 and shown in greater detail in Fig. 2.

The top of the casing 1 may be provided with a suitable head 8, the tubing being supported by said casing and particularly the casing head 8, as by means of a flange 9, suitable bearings indicated at 10 being interposed between the flange 9 and the casing head 8 so as to facilitate rotation of the tubing upon the head 8. An emergency gate valve 11 may be provided and a swivel joint 12 installed in the tubing above the gate valve 11 so that the tubing can be rotated in either direction without interfering with the flow line 13.

One form of valve structure 7 is indicated in longitudinal section in Fig. 2. As there shown, this valve structure comprises a head 15, a body portion 16 and a connecting member generally indicated at 17. The head 15 may terminate in a pin 18 by means of which it may be threadedly connected to tubing 2' or directly to the blow-out preventer 6, shown in Fig. 1. The body portion 16 may be connected at its lower end to the casing 2' or directly to the packer 4, shown in Fig. 1. The lower portion of the body 16 may be provided with a relatively large axial bore, indicated at 19, in communication with a small diameter axial bore 20 which is in alignment with a similar small diameter axial bore 21 extending through the head 15 of the valve.

The upper end of the body portion 16 may be provided with a conical central member 22 adapted to slidably fit into a conical axial depression or seat formed in the bottom of the head member 15 and indicated at 23. Ball bearings or other suitable anti-friction means, indicated at 24, are positioned between the body portion 16 and the head 15 of the valve structure, thereby facilitating relative rotation of the head and body portions of the valve.

Means are provided for preventing longitudinal separation or movement of the head 15 and the body portion 16 of the valve. Such means may include a sleeve 25 threadedly connected to the bottom portion 16 and brought into abutting relation with a shoulder 26 formed in said body portion 16. The upper end of the sleeve 25 may be internally threaded so as to receive an annular member 27 adapted to seat upon an outwardly extending shoulder 28 formed in the head 15. A gland member 29 may be threadedly connected to the interior of the member 27, said gland member 29 being adapted to compress packing 30 between the member 27 and the upper portion of the head 15. The space between the upper end of the gland 29 and the casing 2' (or the blow-out preventer 6) may be fitted with a tapering steel ring 31 which can be bolted in place by the bolts indicated at 32, and eliminate the shoulder at the top of the device which might otherwise catch upon obstructions in the well hole.

The axial bore 21 may be lined as by means of a tubular liner 33 extending through the head 15 and threadedly connected to the conical member 22 of the body portion 16. Such tubular member 33 may extend slightly into the tubing 2' and be held therein by means of packing 35 and a gland 36 carried by the pin 18 of the head 15.

The body portion 16 may include means for closing the axial bore 20, said means being operated by partial rotation of the head 15 relatively to the body portion 16 or in any other suitable manner. As shown in Fig. 2, the upper portion of the body 16 is provided with a stopcock 40

rotatably mounted therein and retained in position as by means of lock nuts 41. The stopcock 40 is provided with a gear 42 in mesh with a gear or gear segment 43 carried by the lower end of the head 15. Partial rotation of the head 15 relatively to the body portion 16 of the device will therefore cause a rotation of the stopcock 40, thereby placing the transverse passageway 44 of said stopcock selectively into communication with the axial bore 20 of the body 16.

The head 15 of the device is provided with an arcuate slot 45 whereas the sleeve member 25 is provided with a pin 46 threaded therein, said pin 46 extending into the arcuate slot 45. The slot 45 is of such length as to permit rotation of the head 15 sufficiently to either place the transverse passageway 44 in communication with the axial bore 20, or transversely thereto. Other suitable means for regulating the operation of the valve 40 may be employed.

As shown in Fig. 2, the body portion 16 of the device is provided with a bore of large diameter 19, said bore being in communication with the tubing section 2" and with the perforated or slotted tubing 3. Preferably the bore of the body portion 16 becomes of gradually decreasing transverse section and leads to the relatively restricted axial bore 20 and valve positioned therein, whereby fluid rising upwardly in the tubing 2" is directed into the axial bore 20 and the velocity of said fluid increased. The structure shown in Fig. 2 has been found to satisfactorily answer these requirements and may include a conical member 48 threadedly connected into the lower end of the axial bore 20, said conical member 48 being provided with an opening or aperture of minimum diameter at a point adjacent to the valve 40, said aperture of minimum diameter formed in the conical member 48 being somewhat smaller than the diameter of the passageway 44 formed in the stopcock 40. By reason of such construction and proportions, fluid rising upwardly through the body portion 16 of the device has its velocity gradually increased and is then discharged at high velocity through the narrow opening indicated at 49 into the passageway 44 of the stopcock 40 without actually contacting with said stopcock. In this manner, cutting action of the upwardly rising fluid upon the valve 40 is eliminated.

As has been stated hereinbefore, the packer 4 (Fig. 1) positioned immediately beneath the valve device 7, subdivides the well hole assembly into two zones A and B. In the operation of the device and in the carrying out of the method of this invention, it is desirable to maintain a pressure in zone A which is substantially equal to, or in excess of, the pressure in zone B. Furthermore, the method of this invention contemplates the utilization of pressure existing in zone A whenever the pressure in zone B drops to a predetermined point below that in zone A.

In order to permit these operations to be carried out, the body portion 16 of the valve device may be provided with valve means adapted to discharge pressure from zone B into zone A whenever the pressure in zone B exceeds that in zone A and to discharge pressure from zone A into zone B, or into the body portion of the valve device, whenever the pressure in zone A exceeds that in zone B by a predetermined amount. Such valve means may include a nipple 50 threadedly connected to the walls of the body portion 16 and extending across the bore 19 therein. A valve seat 51 is carried by the nipple and trans-

verse ports 52 are formed in the walls of the nipple, said ports discharging into the bore 19. A ball valve 53 is normally retained on the seat 51 by means of a spring 54 retained within the nipple by means of a plug 55. The spring 54 is sufficient to maintain the ball 53 on its seat unless the fluid acting upon the valve exceeds the pressure within the bore 19 by a predetermined amount, say 200 pounds. The valve body portion 16 may also be provided with a second nipple 60 threadedly connected into the walls of the body portion 16 and extending across the bore 19, one end of said nipple being provided with a longitudinally ported plug 61 and the other end being closed by a plug 62. The nipple 60 is provided with a seat 63 adapted to receive a ball valve 64 normally maintained on said seat by means of a spring 65 positioned between the spider 61 and said ball valve.

Ports 66 are formed in the side walls of the nipple 60 whereby fluid within the axial bore 19 may pass into the nipple and past the ball valve 64 and be discharged into the space exteriorly of the device through the spider 61 whenever the pressure within the axial bore 19 exceeds the pressure exteriorly of the device.

From the description given hereinabove, it will be evident that in use the string of tubing provided with the perforated or slotted section 3 and packer 4 and valve assembly 7, is lowered into the well hole through the casing 1. The packer 4 may be of such type that when a portion of the weight of the tubing 2 rests upon the packer, it expands and forces a tight seal between the tubing or tubing section 2" and the casing 1. Most of the weight of the tubing may be supported, however, upon the head 8 of the casing. As soon as the device has been lowered into the well hole, the pressure valves 50 and 60 are placed into operation so that the pressure within the upper zone A between the tubing and the casing becomes substantially equal to the pressure beneath the packer 4 in zone B. When the device is lowered into the well hole attached to the bottom portion of the string of tubing 2, the valve 40 is closed.

After such device is lowered into the well hole and the head 8 applied to the casing and the entire device is in operating position, valve 11 may be opened and the string of tubing 2 then partially rotated so as to rotate the head 15 of the valve 7, causing the valve 40 to rotate, thus placing the passageway 44 in communication with the conduit or bore 20. Oil present in the bottom of the well hole will be forced upwardly through the tubing into the body portion 16 of the valve and then through the converging cone member 48 into the axial passageways 20 and 21.

It will be apparent that the velocity of the oil is rapidly increased as it passes upwardly through the cone-shaped member 48 and such rapid increase in velocity followed by the ejection of the oil through the narrow aperture 49 into the passageway 20 and from the passageway or bore 21 into the tubing 2", causes the rapid evolution of gas from solution in the oil. This dynamic velocity of the liberated or evolved gases is utilized in forcing the oil upwardly through the tubing 2. In effect, the device acts as a separator between oil and gas at near the bottom of the well hole. It will be obvious to those skilled in the art that inasmuch as the tubing 2 has been lowered with the valve 40 in

closed position, the oil does not have to overcome any appreciable head when the valve 40 is opened.

After a prolonged operation of this device in the manner described, the pressure in zone B may drop below that existing in zone A. When the pressure in zone B drops to a predetermined degree below that pressure which exists in zone A, the valve 50 will function to admit fluid from zone A into the bore 19 of the valve body portion 16 and in this manner, the upward flow of oil will continue. As a matter of fact, it may be desirable to periodically pump fluid such as a gas or mixture of gases, into the casing 1 so as to maintain the pressure in zone A appreciably above the pressure existing in zone B.

When it is desired to shut down the well, the string of tubing 2 is partially rotated from the surface, thus causing the head 15 to actuate the stopcock 40, closing the same. After closing the valve, it will be observed that the flow of oil will continue for an appreciable length of time, the flowing pressure in the tubing dropping gradually over a period of 10 to 30 minutes. It has been found that substantially all of the oil and gas contained in the tubing 2 will be discharged therefrom after the valve 40 has been closed, so that at any subsequent time the flow of oil from the well hole may be initiated by merely opening the valve 40 by partial rotation of the tubing 2. The pressure on the casing is ordinarily not affected by flowing the well.

From the description given hereinabove, those skilled in the art will observe that a method has been disclosed whereby wells normally incapable of flowing naturally may be caused to flow by reason of the action of gas normally dissolved in the oil. The length of life of flowing wells may thus be prolonged very materially and a greater quantity of oil recovered from a formation than is ordinarily possible.

The method and apparatus of the present invention is of particular value for controlling and regulating the flow of oil and gas from wells which are to be operated on a pro-ration program. When wells are operated on a pro-ration program, it is required that the wells be frequently shut down and started up. The normal method of shutting down an oil well results in the oil tubing being filled with oil to a considerable height in the well. During the period that the well is shut down, this oil loses its gas and life and will not flow naturally when the well is again opened up. By the process and apparatus of the present invention, the well is shut off, or substantially at the producing formation. Any oil in the tubing above the shut-off valve is left free to continue to flow out from the tubing. As a result, there is no stagnant head of oil in the tubing, and when the valve is again opened the well will generally immediately begin to flow.

It is to be understood that the invention is not limited in its operation to the specific form of apparatus described in detail hereinabove, but instead is of the scope of the appended claims.

I claim:

1. A method of regulating the flow of oil and gas from wells provided with a string of tubing and a casing, which comprises: preventing free fluid flow between the casing and tubing in a well hole so as to form a pressure storage zone in the space between said casing and tubing above a point near the bottom of the well hole; permit-

ting fluid flow to take place from the bottom of the well hole into said storage zone; controllably permitting flow of fluid from the bottom of the well upwardly through said tubing and at an increased velocity through a restricted opening at a point near the bottom of said storage zone so as to cause the well to flow; and admitting fluid from said storage zone into said tubing at a point below said opening whenever the pressure in the tubing drops below a predetermined degree whereby gas is removed from solution in fluid by reason of increased velocity and reduced pressure and the dynamic velocity of the gas is caused to lift fluid out of the well hole through the said tubing.

2. A method of regulating the flow of oil and gas from wells provided with a string of tubing and a casing, which comprises: preventing free fluid flow between the casing and tubing in a well hole so as to form a pressure storage zone in the space between said casing and tubing above a point near the bottom of the well hole; permitting fluid flow to take place from the bottom of the well hole into said storage zone; controllably permitting flow of fluid from the bottom of the well upwardly through said tubing and at an increased velocity through a restricted opening at a point near the bottom of said storage zone so as to cause the well to flow; admitting fluid from said storage zone into said tubing at a point below said opening whenever the pressure in the tubing drops below a predetermined degree, whereby gas is removed from solution in fluid by reason of increased velocity and reduced pressure and the dynamic velocity of the gas is caused to lift fluid out of the well hole through the said tubing; and selectively discontinuing the flow of fluid from the bottom of the well hole upwardly through said tubing by closing said opening in the tubing near the bottom of said storage zone.

3. In a method of controlling the flow of oil and gas from wells, the steps of lowering a string of tubing closed axially near its bottom end into a well hole, forming a barrier between the tubing and casing near the bottom of the well hole to form a zone above the barrier between said tubing and casing and a zone below said barrier, permitting discharge of excess pressure fluid from the zone below the barrier into the zone above the barrier, discharging pressure fluid from above the barrier into the zone below the barrier whenever the pressure above the barrier exceeds the pressure below the barrier by a predetermined amount, forming a restricted axial opening in said tubing near its bottom end but above said barrier, and permitting oil and pressure fluid from the zone above the barrier to pass through said axial opening, whereby gas is removed from solution in the oil while passing through said opening, permitting said gas to expand and lift oil out of said well hole through said tubing, and selectively discontinuing the said liberation of gas by closing said opening in said tubing near the bottom thereof.

4. An apparatus for selectively regulating the flow of oil and gas from wells, comprising a casing, a string of tubing in said casing, said tubing extending into an oil strata, a packer carried by the lower portion of the tubing and adapted to seal off the casing from the oil strata, a valve assembly in said tubing above said packer but near the bottom of the tubing string, valve means carried by the tubing between the packer and valve assembly adapted to permit the passage of fluid from within the tubing to the space exteriorly of

the tubing above the packer when the pressure in the latter space is below that within the tubing, and to admit fluid from said exterior space into the tubing when the pressure in said exterior space exceeds that within the tubing by a predetermined amount, said valve assembly including an axial bore of small diameter relatively to said tubing, conical means adapted to direct upwardly flowing fluid in said tubing through said restricted axial bore, and a valve adapted to selectively open and close said axial bore, said valve being operable from the surface by rotation of said tubing.

5. An apparatus for selectively regulating the flow of oil and gas from wells, comprising a casing, a string of tubing in said casing, said tubing extending into an oil strata, a packer carried by the lower portion of the tubing and adapted to seal off the casing from the oil strata, a valve assembly in said tubing above said packer but near the bottom of the tubing string, valve means carried by the tubing between the packer and valve assembly adapted to permit the passage of fluid from within the tubing to the space exteriorly of the tubing above the packer when the pressure in the latter space is below that within the tubing, and to admit fluid from said exterior space into the tubing when the pressure in said exterior space exceeds that within the tubing by a predetermined amount, said valve assembly including a head attached to tubing thereabove, a body portion attached to said packer, a sleeve member connecting said body and head and adapted to prevent longitudinal movement therebetween, bearings between said body and head adapted to facilitate rotation of said head relatively to said body, an axial bore of small diameter relatively to said tubing extending through said body and head, a stopcock in said body portion in operative relation to said axial bore, and means operatively connecting said stopcock and head for selectively opening and closing said stopcock by rotation of said head relatively to said body.

6. An apparatus for selectively regulating the flow of oil and gas from wells, comprising a casing, a string of tubing in said casing, said tubing extending into an oil strata, a packer carried by the lower portion of the tubing and adapted to seal off the casing from the oil strata, a valve assembly in said tubing above said packer but near the bottom of the tubing string, valve means carried by the tubing between the packer and valve assembly adapted to permit the passage of fluid from within the tubing to the space exteriorly of the tubing above the packer when the pressure in the latter space is below that within the tubing, and to admit fluid from said exterior space into the tubing when the pressure in said exterior space exceeds that within the tubing by a predetermined amount, said valve assembly including a head attached to tubing thereabove, a body portion attached to said packer, a sleeve member connecting said body and head and adapted to prevent longitudinal movement therebetween, bearings between said body and head adapted to facilitate rotation of said head relatively to said body, an axial bore of small diameter relatively to said tubing extending through said body and

head, a stopcock in said body portion in operative relation to said axial bore, means operatively connecting said stopcock and head for selectively opening and closing said stopcock by rotation of said head relatively to said body, and a flow directing device in such body portion, said flow directing device being provided with an aperture of smaller diameter than said axial bore whereby fluid may be directed through said stopcock without substantial contact therewith.

7. An apparatus for selectively regulating the flow of oil and gas from wells, comprising a casing, a string of tubing in said casing, said tubing extending into an oil strata, a packer carried by the lower portion of the tubing and adapted to seal off the casing from the oil strata, a valve assembly in said tubing above said packer but near the bottom of the tubing string, valve means carried by the tubing between the packer and valve assembly adapted to permit the passage of fluid from within the lower portion of the tubing to the space exteriorly of the tubing above the packer when the pressure in the latter space is below that within the tubing and to admit fluid from said exterior space into the tubing when the pressure in said exterior space exceeds that within the tubing by a predetermined amount, said valve assembly including an upwardly directed conical bore discharging into a bore not exceeding in diameter the size of the tubing bore at any point thereabove, the conical bore terminating in a restricted opening of smaller diameter than the tubing bore thereabove, and an adjustable closure member adjacent to said restricted opening, said closure member being selectively operable from the surface by rotation of said tubing whereby when said closure is opened the velocity of upwardly moving oil is increased by passage through said conical bore, and gas is liberated from solution in the oil by the discharge of oil from the small end of said conical bore into the larger tubing bore, said gas lifting oil upwardly along said tubing bore.

8. An apparatus for regulating the flow of oil and gas from wells, comprising a casing, a string of tubing in said casing, said tubing extending into an oil strata, a packer carried by the lower portion of the tubing and adapted to seal off the casing from the oil strata, a valve assembly in said tubing above said packer but near the bottom of the tubing string, said valve assembly including an axial bore of small diameter relative to such tubing, substantially conical means adapted to direct upwardly flowing fluid in said tubing through said restricted axial bore, a valve adapted to selectively open and close said axial bore, said valve being operable from the surface of rotation of said tubing, and additional valve means adapted to permit passage of fluid from within the tubing and below said valve assembly to the space exterior of the tubing above the packer when the pressure in the latter space is below that within the tubing and to admit fluid from said exterior space into the tubing at a point below said restricted axial bore when the pressure in said exterior space exceeds that within the tubing by a predetermined amount.

ERLE P. HALLIBURTON.